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Yield Model Development

EVALUATION OF THE CEAS TREND AND MONTHLY WEATHER DATA MODELS FOR SOYBEAN YIELDS IN IOWA, ILLINOIS, AND INDIANA

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16. Abstract

The CEAS models evaluated use historic trend and meteorological and agroclimatic variables to estimate soybean yields in Iowa, Illinois, and Indiana. CRD and state models are evaluated. Yield reliability at the state level shows that the bias is less than one-half quintal/hectare. The standard deviation is between one and two quintals/hectare. The models are adequate in terms of coverage and show some consistency with scientific knowledge. Timely yield estimates can be made during the growing season using truncated models. The models are easy to understand and use. The models are objective, but the objectivity and cost of redevelopment of the models is difficult to assess. The model standard errors of prediction are not useful as a current measure of modeled yield reliability.

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EVALUATION OF THE CEAS TREND
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FOR SOYBEAN YIELDS IN
IOWA, ILLINOIS, AND INDIANA

BY
VIKKI FRENCH

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Evaluation of the CEAS Trend and Monthly Weather Data Models for Soybean Yields in Iowa, Illinois, and Indiana

Vikki French

SUMMARY AND CONCLUSIONS

The CEAS models evaluated use historic trend and meteorological and agroclimatic variables to forecast soybean yields in Iowa, Illinois, and Indiana. Indicators of yield reliability and current measures of modeled yield reliability were obtained from bootstrap tests on th end-of-season models.

Indicators of yield reliability show that the state models are consistently better than the CRD models. One CRD model is especially poor. At the state level, the bias of each model is less than one half quintal/hectare. The standard deviation is between one and two quintals/hectare. The models are adequate in terms of coverage and are to a certain extent consistent with scientific knowledge. Timely yield estimates can be made during the growing season using truncated models.

The models would be easy to understand and use. The models are not costly to operate. Other than the specification of values used to determine evapotranspiration, the models are objective. Because the method of variable selection used in the model development has not been adequately documented, no evaluation can be made of the objectivity and cost of redevelopment of the model.

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DESCRIPTION OF THE MODELS

The models were developed by the Climatic and Environmental Assessment Services (CEAS) (Motha, 1980) to predict soybean yields for the states of Iowa, Illinois, and Indiana and for Crop Reporting Districts (CRDs) within each state. CEAS is a part of the National Oceanic and Atmospheric Administration (NOAA) within the U.S. Department of Commerce.

Historic data were used to develop the models. The variables in the historic data set are year, yield, monthly average temperature (T) and total monthly precipitation (P). Agroclimatic variables were derived from monthly temperature and precipitation. Trend terms were developed based on a function of the year number. The variables included in each model are listed in the Appendix.

The meteorological variables used in the models include average monthly temperature (T1 - T12 for January - December), cumulative precipitation (CPREC), deviations from normal temperature and precipitation (DFNT and DFNP), and squared deviations from normal precipitation (SDFNP), a quadratic term.

Agroclimatic variables which were felt to better represent the impact of moisture and heat stress were also calculated. Moisture is supplied by water stored in the soil and is replenished by rainfall. Moisture is lost from the available water capacity of the soil directly through evaporation and indirectly through transpiration from the plants. Actual evapotranspiration (ET) is defined as the actual water loss by transpiration from the leaves and by evaporation from the underlying surface. Potential evapotranspiration (PET) is defined as the maximum possible ET which would occur if soil moisture over a large area were not a limiting factor. An approximation to the montly PET is calculated using a procedure developed by Thornthwaite (1948). The calculations require the current and "normal" monthly temperature and the latitude of the geographic location. ET can then be calculated as a function of PET, monthly precipitation, and the budgeting of available soil moisture. The soil moisture budget is maintained according to Palmer (1965). Evapotranspiration which is considered to be "climatically appropriate for existing conditions" (CAFEC) is computed as αPET, where α = $\overline{ET}/\overline{PET}$ AND $\overline{ET}$ and $\overline{PET}$ are long term averages for a particular month. This quantity indicates the value ET would have in order to be in its historic ratio to PET. Variables in the models indicating moisture stress are DEF = P - PET and RATIO = ET/CAFEC(ET).

Linear functions of year are used as surrogates for technology in all models. Two linear trend terms are used for Iowa and Illinois, and a single trend term is used for Indiana. For both Iowa and Illinois, the first trend term (TREND 1) is derived by subtracting 1930 from each year value up to and including 1960 starting from the earlist year for which historic yield data is available, 1950 for Iowa and 1932 for Illinois. For years after 1960, the constant value "30" is used. The second trend term (TREND 2) uses the value "30" for all years prior to 1960 and the year value minus 1930 for all years after 1960 up to 1978. The trend for Indiana (TREND) is definded by subtracting 1930 from each year value from the earliest year, 1937, up to 1978. There is no explanation as to how these trend variables were determined (Motha, 1980). It is not clearly specified whether these trend terms should be continued.

No discussion is included as to the method of selecting variables for inclusion in the models, but some combination of stepwise regression and subjective judgment seems to have been used.

The weather variables for the state models, including the derived variables, are weighted averages of the variables as calculated for each CRD in the state. The weight used is harvested area, although planted area is suggested for estimating yield in the current year. Models were independently developed for each CRD and state using the same combination of procedures. Weather and yield data from 1950 to 1978 for Iowa, 1932 to 1978 for Illinois and 1937 to 1978 for Indiana were used to develop the models.

Exclusion or modification of any yields because of the known occurrence of episodic events, such as hail or disease damage, is not mentioned.

EVALUATION METHODOLOGY

Eight Model Characteristics to Be Discussed

The document, Crop Yield Model Test and Evaluation Criteria, (Wilson, et. al., 1980), states:

> The model characteristics to be emphasized in the evaluation process are: yield indication reliability, objectivity, consistency with scientific knowledge, adequacy, timeliness, minimum costs, simplicity, and accurate current measure of modeled yield reliability.

Each of these characteristics will be discussed with respect to the CEAS trend and monthly weather data soybean yield models.

Bootstrap Technique Used to Generate Indicators of Yield Reliability for the End-of-Season Models

Indicators of yield reliability (reviewed below) require that the parameters of the regression model be computed for a set of data and that a yield prediction be made based on that data for a given "test" year. The values required to generate indicators of yield reliability include the predicted yield, $\hat{Y}$, the actual (reported) yield, Y, and the difference

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between them, $d = \hat{Y}-Y$, for each test year. It is desirable that the data used to generate the parameters for the model not include data from the test year.

To accomplish this, a "bootstrap" technique is used. Years from an earlier base period are used to fit the model and obtain a prediction equation. The values of the independent variables for the test year following the base period are inserted into the equation and a predicted yield is generated. That test year is then added to the base period and the process is repeated for the next sequential test year. Continuing in this way, ten (1970-1979) predictions of yield are obtained, each independent of the data used to fit the model.

For Iowa, data for 1950-1969 (20 years) is used to fit prediction models for 1970; data for 1950-1970 (21 years) is used to fit prediction models for 1971, etc. For Illinois, data for 1932-1969 (38 years) is used to fit prediction models for 1970; data for 1932-1970 (39 years) is used to fit prediction models for 1971, etc. For Indiana, data for 1937-1969 (33 years) is used to fit prediction models for 1970, etc.

Even though the data used to estimate the regression coefficients do not include the test year, this procedure does not result in a predicted yield which is totally independent of the data from the test year. The model developer used data through 1978 (which includes nine of the test years) to select the variables which are included in each model and to determine the break points for trend. It is unrealistic to require the model developer to develop ten models for each test year. Since the procedures used for variable selection and break point determination include subjective decisions, the process cannot be simulated accurately by the model evaluator. Therefore, the bootstrap procedure described, neither tests how well these models can perform in the future if the procedure is repeated nor how well the model developer can incorporate future changes in trend.

Average soybean production and yield over the ten year test period are listed in Table 1 for each geographic area. Also shown is the percent of production each CRD contributes to its state and the two state region and the percent of production each state contributes to the region. The percentage of regional production for each CRD is shown graphically in Figure 1. Darker shades indicate higher average productivity.

Separate models are derived for each CRD in Iowa, Illinois, and Indiana and for each of the three states. Predicted yields at the state level are also obtained by using an aggregated, weighted average of that state's CRD predicted yields. Predicted yields for the region are obtained both by aggregating the CRD model yields and from state model yields. In all cases, the weighting factor used is soybean harvested area. Results obtained by aggregating from the CRD models are identified as "CRD Aggr." and aggregating state models as "state aggr." Although models have been developed for use before and during the growing season, they are not included in this discussion and only the reliability of the end-of-season models is examined here.

Review of Indicators of Yield Reliability

The Y, $\hat{Y}$ and d values for the ten-year period at each geographic area may be summarized into various indicators of yield reliability.

Indicators Based on the Difference Between $\hat{Y}$ and Y ($d = \hat{Y}-Y$) Demonstrate Accuracy, Precision and Bias

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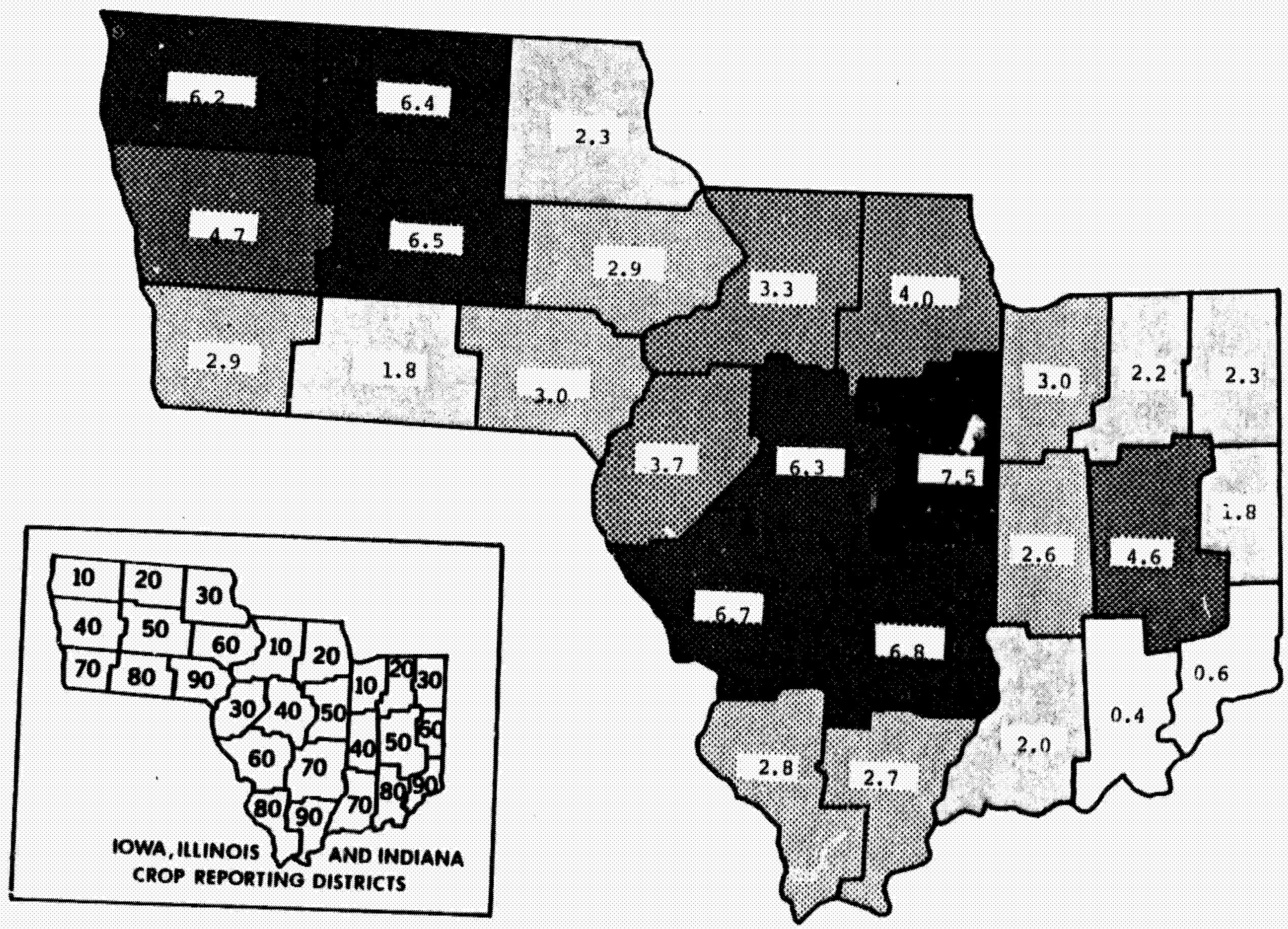
TABLE 1
AVERAGE PRODUCTION AND YIELD
FOR TEST YEARS 1970-79

SOYBEANS
IOWA, ILLINOIS, INDIANA

STATE	CRD	PRODUCTION (1,000) QUINTALS	PRODUCTION (1,000) BUSHELS	PERCENT OF STATE	PERCENT OF REGION	YIELD QNTL/HA	YIELD BU/ACRE
IOWA	10	10.677	39.229	16.9	6.2	23.3	34.6
	20	10.954	40.250	17.4	5.4	22.7	33.7
	30	3.901	14.335	6.2	2.3	21.6	32.1
	40	8.171	30.024	13.0	4.7	22.2	33.0
	50	11.107	40.810	17.6	6.5	23.7	35.2
	60	4.993	18.344	7.9	2.9	24.3	35.1
	70	5.002	18.377	7.9	2.9	22.0	32.7
	80	3.104	11.407	4.9	1.8	20.2	30.1
	90	5.131	18.854	8.1	3.0	22.9	34.1
STATE		63.040	231.630		36.6	22.8	33.8
ILLINOIS	10	5.664	20.811	7.5	3.3	24.0	35.7
	20	6.959	25.568	9.2	4.0	22.2	33.1
	30	6.329	23.253	8.4	3.7	23.6	35.0
	40	10.899	40.045	14.4	5.3	25.0	37.2
	50	12.878	47.318	17.1	7.5	24.3	35.1
	60	11.502	42.261	15.2	6.7	23.2	34.6
	70	11.715	43.043	15.5	6.8	20.8	31.0
	80	4.881	17.935	6.5	2.8	19.3	29.7
	90	4.685	17.213	6.2	2.7	17.4	25.9
STATE		75,510	277,448		43.9	22.5	33.4
INDIANA	10	5.206	19.129	15.5	3.0	22.1	32.9
	20	3.714	13.647	11.1	2.2	21.8	32.4
	30	3.933	14.453	11.7	2.3	20.9	31.1
	40	4.422	16.246	13.2	2.6	22.6	33.6
	50	8.001	29.398	23.8	4.6	23.6	35.1
	60	3.173	11.659	9.4	1.8	21.1	31.4
	70	3.366	12.369	10.0	2.0	20.6	30.7
	80	738	2.711	2.2	0.4	19.5	27.5
	90	1,058	3.889	3.1	0.6	19.9	29.1
STATE		33.612	123.500		19.5	21.9	32.5
REGION		172,162	632,578			22.4	33.4

Figure 1. Production of soybeans by CRD (1970-79 average) as a percent of the regional total. Darker shades indicate CRDs with higher production.



From the d value, the mean square error (root and relative root mean square error), the variance (standard deviation and relative standard deviation), and the bias (its square and the relative bias) are obtained.

The root mean square error (RMSE) and the standard deviation (SD) indicate the accuracy and precision of the model and are expressed in the original units of measure (quintals/hectare). Assuming the d values are normally distributed, it is about 68% probable that the absolute value of d for a future year will be less than one RMSE and 95% probable that it will be less than twice the RMSE. So, accurate prediction capability is indicated by a small RMSE.

A non-zero bias means the model is, on the average, overestimating the yield (positive bias) or underestimating the yield (negative bias). The SD is smaller than the RMSE when there is non-zero bias and indicates what the RMSE would be if there were no bias. If the bias is near zero, the SD and the RMSE will be close the value. A model whose bias is close to zero is preferred.

Indicators Based on Relative Differences Between $\hat{Y}$ and Y (rd = 100d/Y) Demonstrate Worst and Best Performance

The relative difference, rd, is an especially useful indicator in years where a low actual yield is not predicted accurately. This is because years with small observed actual yields and large differences often have the largest rd values.

Several indicators are derived using relative differences. In order to calculate the proportion of years beyond a critical error limit, we count the number of years in which the absolute value of the relative difference exceeds the critical limit of 10 percent. Values between 5 and 25 percent were investigated and a critical limit of 10 percent was found most useful in describing model performance. The worst and next to worst performance during the test period are defined as the largest and next to largest absolute value of the relative difference. The range of yield indication accuracy is defined by the largest and smallest absolut. valeus of the relative difference.

Indicators Based on $\hat{Y}$ and Y Demonstrate Correspondence Between Actual and Predicted Yields

Another set of indicators demonstrates the correspondence between actual and predicted yields. It is desirable for increases in actual yield to be accompanied by increases in predicted yields. It is also desirable for large (small) actual yields to correspond to large (small) predicted yields.

Two indicators relate the change in direction of actual yields due to the corresponding change in predicted yields. One looks at change from the previous year (nine observations). A base period of three years is used since a longer base period would further decrease the number of observations, while a shorter period would not be very different from the comparison to a single previous year.

Finally, the Pearson correlation coefficient, r, between the set of actual and predicted values for the test years is computed. It is desirable that $r(-1 \leq r \leq +1)$ be large and positive. A negative r indicates smaller predicted yields occurring with larger observed yields (and vice versa).

Current Measure of Modeled Yield Reliability Defined By a Correlation Coefficient

One of the model characteristics to be evaluated is its ability to provide an accurate, current measure of modeled yield reliability. Although a specific statistic was not discussed in the paper, Crop Yield

Model Test and Evaluation Criteria, (Wilson, et al., 1980), it was stated that:

> This 'reliability of the reliability' characteristic can be evaluated by comparing model generated reliability measures with subsequently determined deviation between modeled and 'true' yield.

For regression models, this suggests the use of a correlation coefficient between two variables generated for each test year. One variable is an indicator of the precision with which a prediction for the next year can be made, based on the model development base period. The other variable (obtained retrospectively) is an indicator of how close the predicted value for the next year actually is to the "true" value. The estimate of the standard error of a predicted value form the base period model, $s\hat{Y}$, is often used for the first value, and the absolute value of the difference between the predicted and acutal yield in the test year $|d|$, is used as the second variable.

A non-parametric (Spearman) correlation coefficient, r, is employed since the assumption of bivariate normality cannot be made. A positive value of $r(-1 < r < +1)$ indicates a smaller (larger) value of $s\hat{Y}$ is associated with a smaller (larger) value of $|d|$. An r value close to +1 is desirable since it indicates that a small standard error of prediction (and therefore a narrow prediction interval about the yield being predicted) is associated with small discrepancies between predicted and actual yields. If this were the case, one would have confidence in $s\hat{Y}$ as an indicator of the accuracy of $\hat{Y}$.

A model-related reliability measure other than $s\hat{Y}$ could be suggested for use. In the present case, the model developer did not recommend any measure, so $s\hat{Y}$ is used.

MODEL EVALUATION

Indicators of Yield Reliability Based on $d = \hat{Y} - Y$ Show Bias Usually Less Than 1 Quintal/Hectare and Standard Deviation Less Than 3 Quintals/Hectare

Table 2 shows indicators of yield reliability based on d for CRDs, states, and the region. Figure 2 also shows CRD values for the root mean square error.

The root mean square error (RMSE) is an indication of how accurately each model can predict the yields over the test years. For the CEAS soybean models, the RMSE values are less than 3 quintals/hectare. The state model for Illinois has a smaller RMSE than any of the Illinois CRD models, and the state model RMSE for Indiana is smaller than for any Indiana CRD model except CRD 2. This indicates that these two state models have a higher degree of accuracy than the CRD models.

The standard deviation (SD) indicates the variability of the d values. For Iowa and Illinois these are all less than 3 quintals/hectare. For Indiana they are all less than 2 quintals/hectare.

The bias values for Indiana are mostly negative, indicating that the models tend to underestimate the yields. The bias for all models is less than one quintal/hectare, and, except for Iowa CRD6, the relative bias values are less than 5 percent.

There is no indication that one of the aggregation methods is consistently better than the other at the regional level.

Indicators of Yield Reliability Based on $rd = 100\ d/Y$ Show Less Than 50 Percent of the Years Have rd Greater Than 10 Percent, and Largest rd Less Than 50 Percent

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TABLE 2
INDICATORS OF YIELD RELIABILITY
BASED ON D = PREDICTED - ACTUAL YIELD

CEAS MODEL - SOYBEANS
IOWA, ILLINOIS, INDIANA

MSE, VAR, B-SQR (QUINTALS/HECTARE SQUARED)
RMSE, SD, BIAS (QUINTALS/HECTARE)
RRMSE, RSD, RB (PERCENT OF AVERAGE YIELD)

STATE	CRD	MSE	RMSE	RRMSE	VAR	SD	RSD	B-SQR	BIAS	RB
IOWA	10	4.24	2.06	9.9	4.17	2.04	8.7	0.07	0.26	1.1
	20	1.57	1.25	5.5	1.55	1.25	5.5	0.02	0.15	0.7
	30	2.07	1.44	6.7	1.83	1.35	6.4	0.24	-0.49	-2.3
	40	0.70	0.83	3.8	0.60	0.78	3.5	0.10	-0.31	-1.4
	50	2.48	1.57	6.6	2.45	1.57	6.6	0.03	0.16	0.7
	60	5.19	2.28	9.4	3.15	1.77	6.9	2.04	1.43	5.9
	70	1.98	1.41	6.4	1.76	1.33	5.9	0.22	0.47	2.1
	80	4.88	2.21	10.9	4.01	2.00	9.5	0.86	0.93	4.5
	90	3.21	1.79	7.8	3.20	1.79	7.8	0.01	0.10	0.4
STATE MODEL		2.21	1.49	6.5	2.20	1.48	6.5	0.01	-0.09	-0.4
CRDS AGGR.		1.03	1.02	4.5	0.98	0.99	4.3	0.05	0.23	1.0
ILLINOIS	10	5.06	2.25	9.4	4.91	2.22	9.1	0.15	0.39	1.6
	20	5.54	2.35	10.6	5.16	2.27	10.5	0.38	-0.62	-2.8
	30	6.95	2.64	11.2	6.88	2.62	11.3	0.07	-0.27	-1.1
	40	5.19	2.28	9.1	4.99	2.23	8.8	0.20	0.45	1.8
	50	2.97	1.72	7.1	2.45	1.56	6.3	0.52	0.72	3.0
	60	4.52	2.13	9.1	4.49	2.12	9.1	0.03	0.17	0.7
	70	5.05	2.25	10.8	4.89	2.21	10.4	0.16	0.40	1.9
	80	4.44	2.11	10.9	4.44	2.11	10.9	0.00	0.02	0.1
	90	3.32	1.82	10.5	3.29	1.81	10.5	0.03	-0.15	-0.9
STATE MODEL		2.45	1.57	7.0	2.21	1.49	6.5	0.24	0.49	2.2
CRDS AGGR.		3.46	1.86	9.3	3.42	1.85	8.2	0.04	0.19	0.8
INDIANA	10	2.06	1.44	6.5	1.60	1.26	5.9	0.46	-0.68	-3.1
	20	1.68	1.30	6.0	1.42	1.19	5.6	0.26	-0.51	-2.3
	30	2.44	1.56	7.5	1.92	1.38	6.9	0.52	-0.72	-3.4
	40	4.06	2.02	8.9	3.73	1.93	8.8	0.34	-0.58	-2.6
	50	2.47	1.57	6.7	2.37	1.54	6.6	0.10	-0.32	-1.4
	60	3.04	1.74	8.3	2.96	1.72	8.3	0.07	-0.27	-1.3
	70	3.02	1.74	8.4	3.02	1.74	8.4	0.00	0.01	0.0
	80	3.26	1.80	9.8	3.07	1.75	9.7	0.18	-0.43	-2.3
	90	3.22	1.80	9.5	3.04	1.74	9.5	0.18	-0.43	-2.3
STATE MODEL		1.87	1.37	6.3	1.82	1.35	6.2	0.05	-0.22	-1.0
CRDS AGGR.		1.53	1.24	5.7	1.34	1.16	5.4	0.19	-0.44	-2.0
REGION										
CRDS AGGR.		1.76	1.33	5.9	1.75	1.32	5.9	0.01	0.09	0.4
STATES AGGR.		1.73	1.32	5.9	1.71	1.31	5.8	0.03	0.16	0.7

Figure 2. Root mean square error (RMSE) for CEAS soybean model in quintals per hectare based on test years 1970-1979. Darker shades indicate CRDs with higher production.

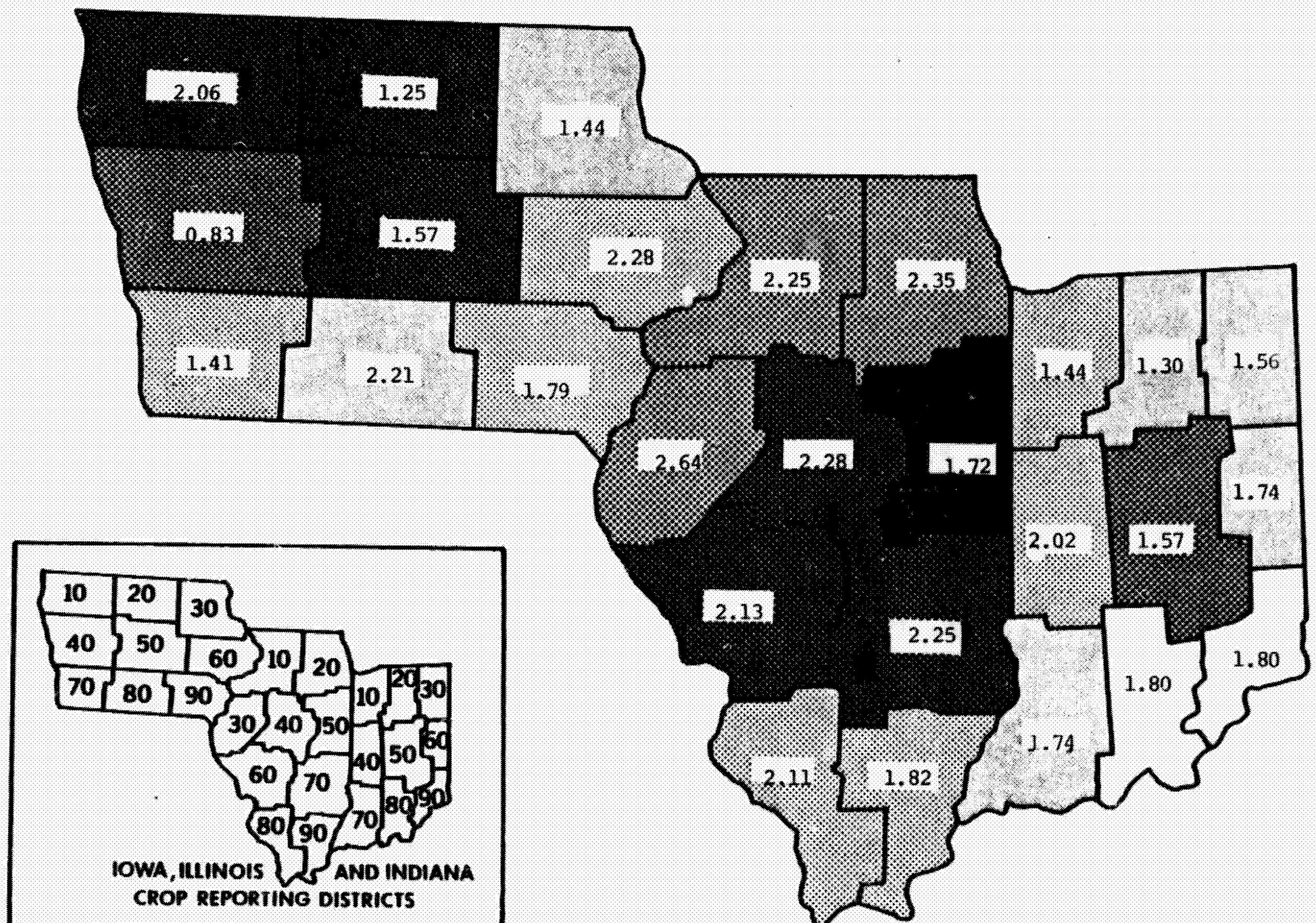


Table 3 gives indicators of yield reliability based on rd for the region, states, and the CRDs. Figures 3-5 also show CRD values for selected indicators.

The Illinois CRD 80 model shows the poorest results; 50 percent of the years have an absolute relative difference greater than 10 percent. Illinois CRDs 20, 70, and 90 have an absolute relative difference greater than 10 percent for 40 percent of the test years.

Most (80%) of the models' largest absolute relative differences occurred for the year 1974, indicating that 1974 was difficult to predict accurately. Growing conditions that could account for this are shown in Appendix A. The largest absolute relative difference is 41.2% for Iowa CRD 80 (1974). The second largest absolute relative differences are all less than 20 percent.

The smallest absolute relative differences are generally less than two percent. The largest was for Illinois CRD 60 which was over four percent.

Again, there is no clear indication that one of the aggregation methods is better at the regional level.

Indicators of Yield Reliability Based on $\hat{Y}$ and Y Show Low Correspondence Between the Direction of Change in Predicted as Compared to Actual Yields

Figures 6, 7 and 8 show plots of the actual and predicted yields using the state level models for the ten-year period. Table 4 shows the indicators of yield reliability based on actual and predicted yields for CRD. states, and the region. Figures 9-11 also show CRD values.

For most of the models, the change in direction of predicted yields agrees with the change in direction of actual yields both from the previous year and from the average of the three previous years over fifty percent

TABLE 3
INDICATORS OF YIELD RELIABILITY
BASED ON RD = 100 * ((PREDICTED-ACTUAL YIELD)/ACTUAL YIELD)

CEAS MODEL - SOYBEANS
IOWA, ILLINOIS, INDIANA

STATE	CRD	PERCENT OF YEARS |RD|>10%	LARGEST |RD| RD (YEAR)	NEXT LARGEST	SMALLEST |RD|	RANGE |RD|
IOWA	10	20	18.2 (1974)	-13.0	0.4	17.9
	20	10	13.4 (1974)	7.9	0.0	13.4
	30	20	10.9 (1974)	-10.0	-0.8	10.1
	40	0	-6.7 (1974)	5.0	0.0	6.7
	50	10	20.7 (1974)	-7.3	0.9	19.9
	60	20	28.6 (1974)	11.5	-0.5	27.9
	70	10	12.7 (1978)	5.1	-0.4	12.3
	80	30	41.2 (1974)	11.3	2.2	38.9
	90	20	16.7 (1974)	-11.7	0.0	16.7
STATE MODEL		20	-10.3 (1975)	10.7	-0.8	10.1
CRDS AGGR.		10	14.9 (1974)	-3.7	0.0	14.9
ILLINOIS	10	10	37.1 (1974)	5.3	0.4	36.5
	20	40	22.4 (1974)	-14.0	-1.0	21.4
	30	30	34.3 (1974)	-15.6	-1.7	32.5
	40	10	38.3 (1974)	5.6	-1.2	37.1
	50	10	23.3 (1974)	9.7	2.0	21.2
	60	20	23.0 (1974)	-12.0	4.3	18.7
	70	40	28.9 (1974)	-12.9	1.9	27.1
	80	50	20.8 (1974)	-13.5	-1.5	19.3
	90	40	19.2 (1978)	18.7	-1.3	17.9
STATE MODEL		10	22.4 (1974)	9.0	0.9	21.5
CRDS AGGR.		10	27.3 (1974)	-7.5	0.5	26.5
INDIANA	10	20	-11.6 (1977)	11.0	0.5	11.1
	20	10	-12.6 (1975)	-7.0	-0.4	12.2
	30	20	13.2 (1974)	-12.2	-0.5	12.7
	40	30	25.8 (1974)	-14.0	1.2	24.5
	50	10	17.4 (1974)	-9.0	-0.4	17.0
	60	20	23.1 (1974)	-11.6	-0.5	22.5
	70	20	17.2 (1979)	-10.6	-1.4	15.9
	80	30	-19.8 (1974)	17.9	1.0	17.9
	90	40	13.7 (1972)	-13.3	-0.5	13.1
STATE MODEL		10	16.1 (1974)	-7.2	1.5	14.5
CRDS AGGR.		10	11.9 (1974)	-8.8	-0.9	11.0
REGION MODEL						
CRDS AGGR.		10	19.5 (1974)	-5.2	-0.5	19.1
STATES AGGR.		10	14.4 (1974)	8.1	-0.4	13.9

Figure 3. Percent of test years (1970-1979) the absolute value of the relative difference from the CEAS soybean models is greater than ten percent. Darker shades indicate CRDs with higher production.

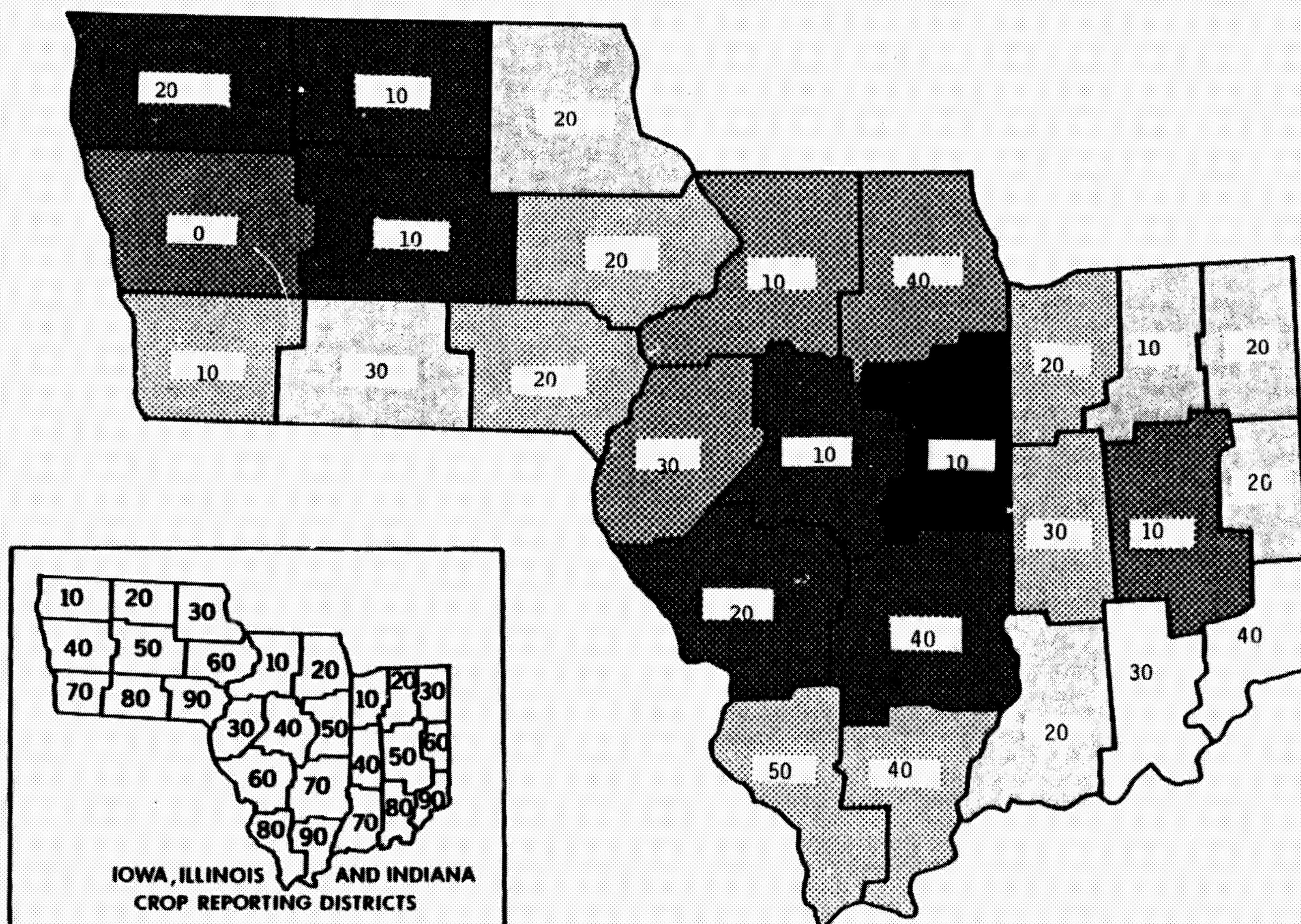


Figure 4. Largest absolute value of the relative difference from the CEAS soybean models during the test years 1970-1979. Darker shades indicate CRDs with higher production.

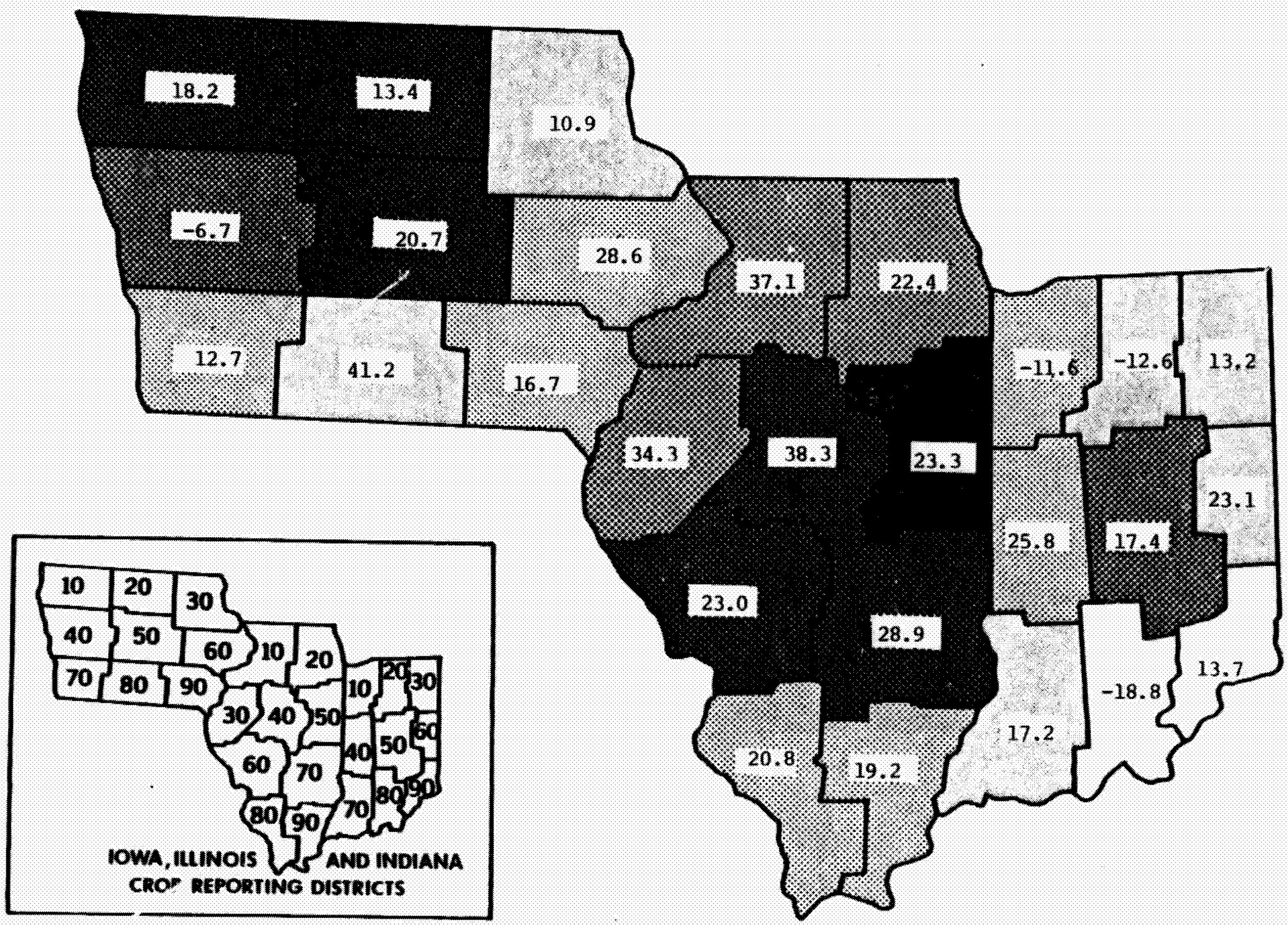
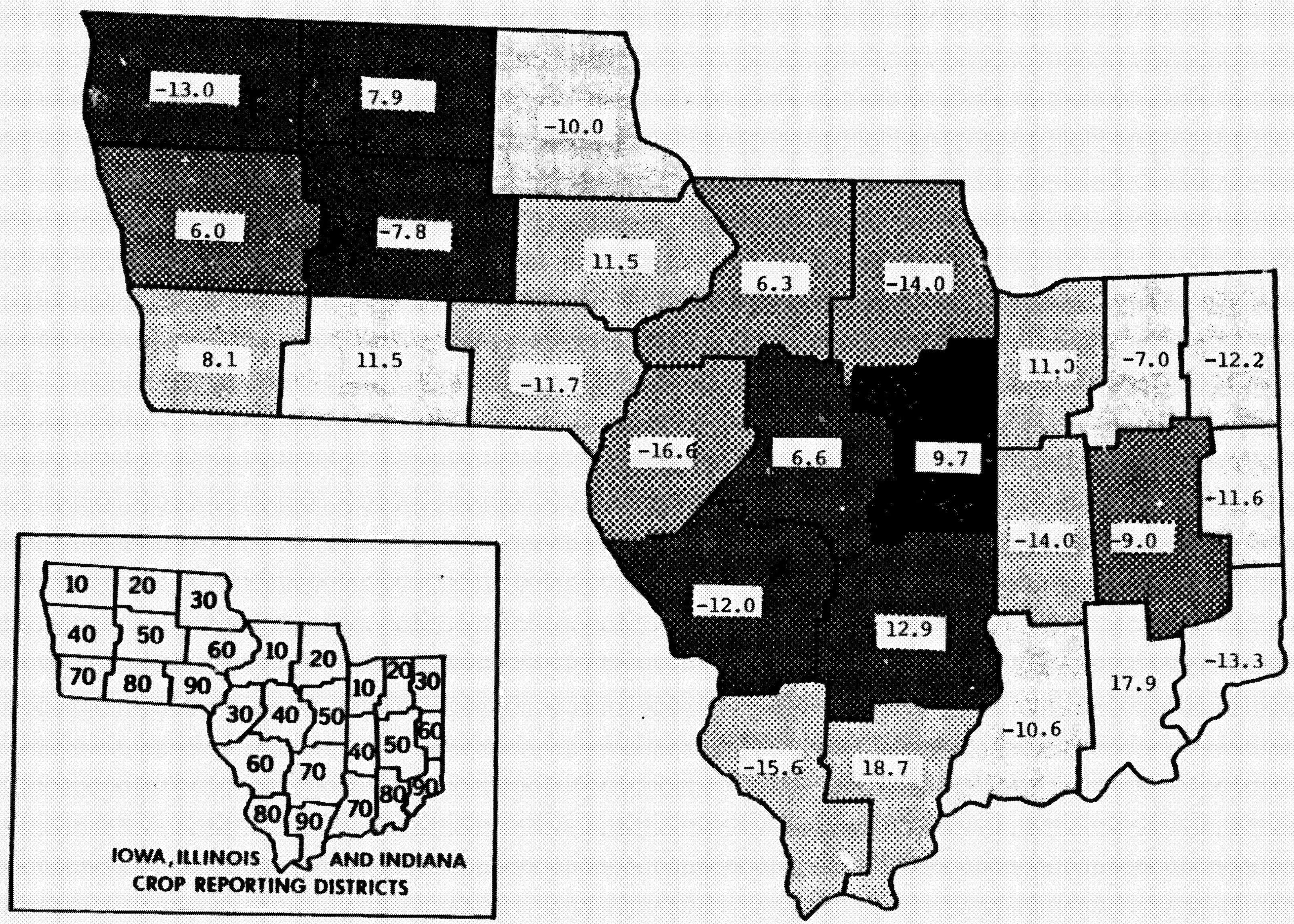
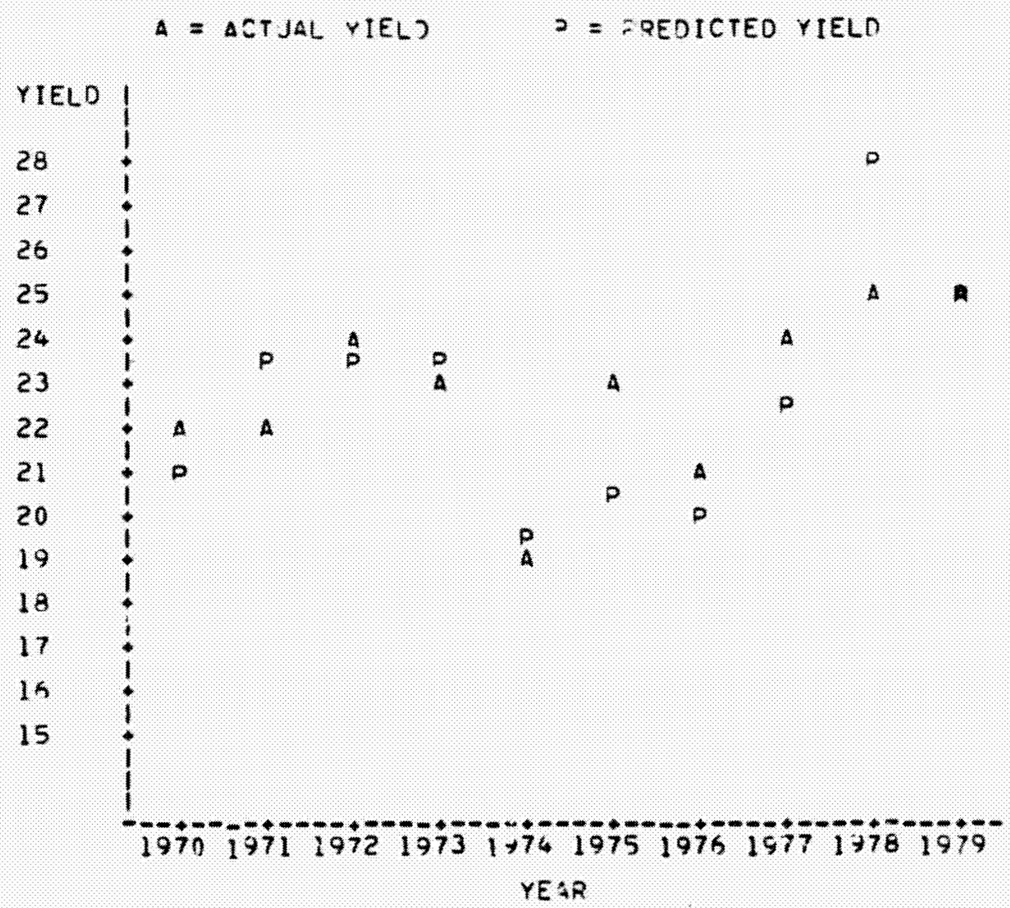


Figure 5. Next largest absolute value of the relative difference from the CEAS soybean models during the test years 1970-1979. Darker shades inidcate CRDs with higher production.



Iowa State Model, actual and predicted soybean yields for the test years 1970-1979

Figure 6



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Illinois State Model, Actual and Predicted Soybean
Yields for the Test Years 1970-1979

Figure 7

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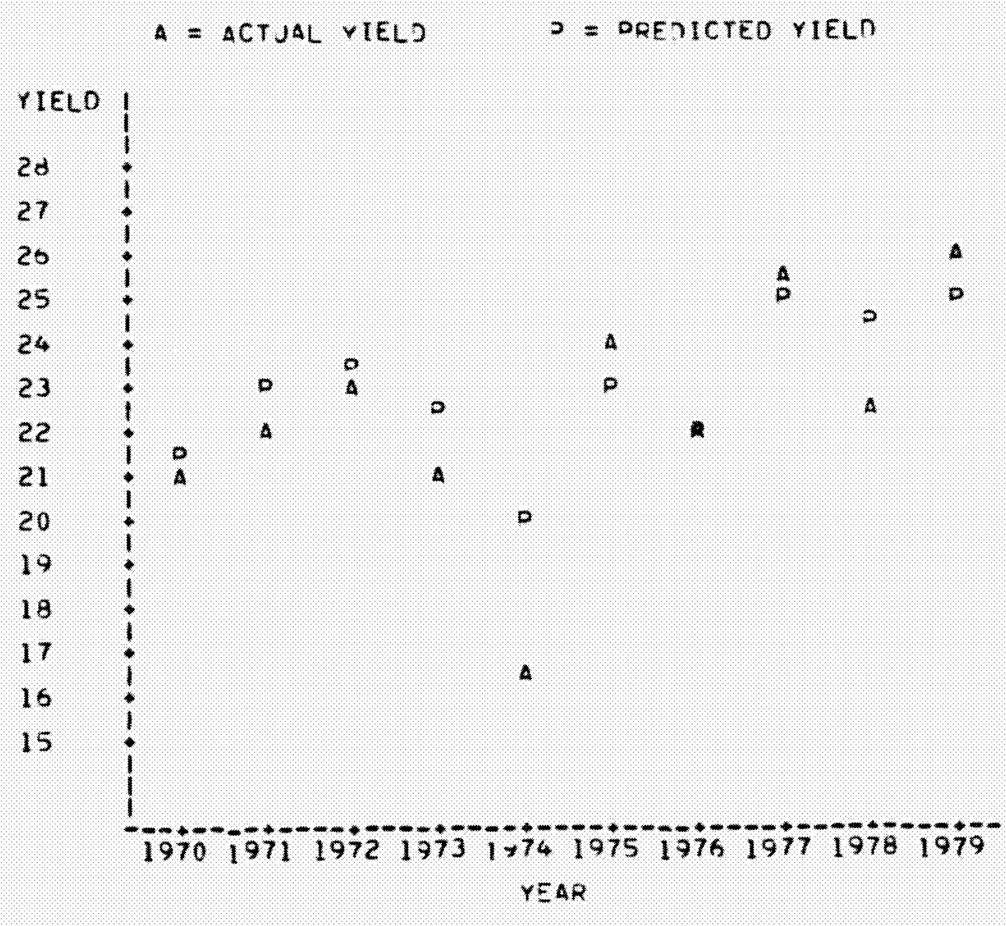

Indiana State Model, Actual and Predicted
Soybean Yields for the Test Years 1970-1979

Figure 8

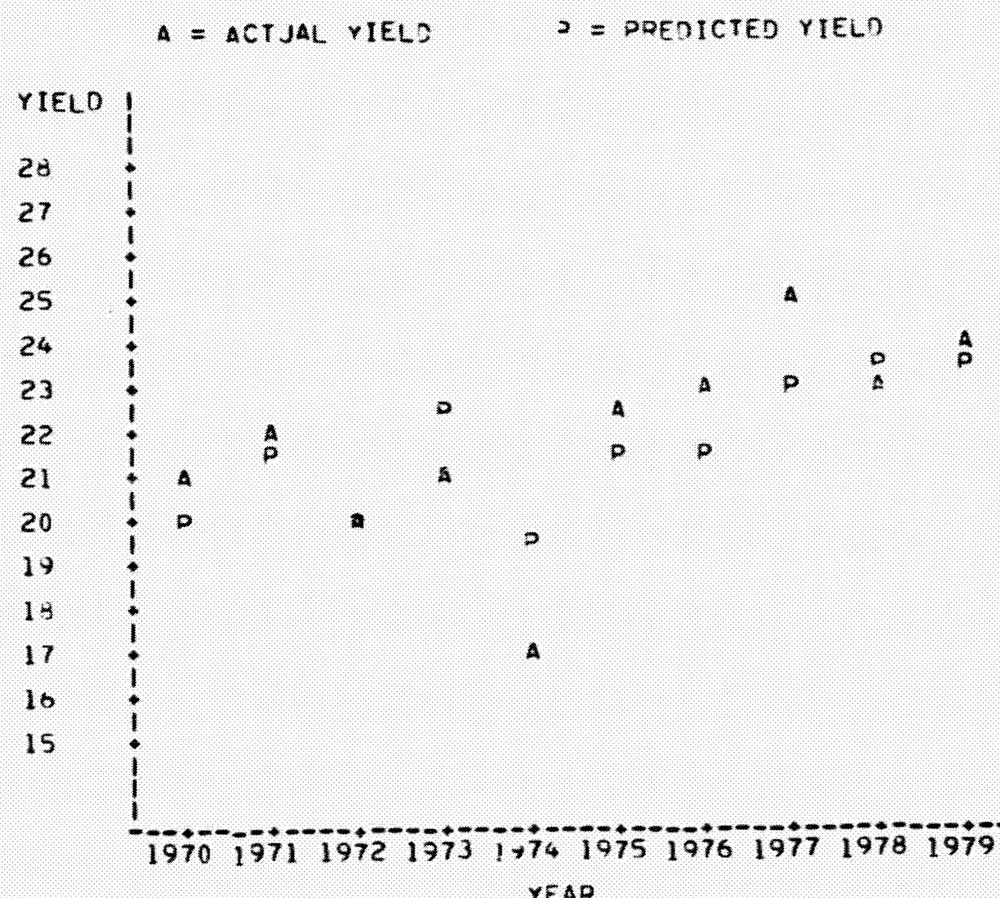

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TABLE 4
INDICATORS OF YIELD RELIABILITY
BASED ON ACTUAL AND PREDICTED YIELDS

CEAS MODEL - SOYBEANS
IOWA, ILLINOIS, INDIANA

STATE	CRD	PERCENT OF YEARS DIRECTION OF CHANGE IS CORRECT FROM PREVIOUS YEAR	FROM BASE PERIOD	PEARSON CORR. COEF.
IOWA	10	67	86	0.75
	20	33	71	0.55
	30	44	57	0.79
	40	89	100	0.96
	50	89	86	0.76
	60	89	57	0.49
	70	78	71	0.68
	80	67	43	0.55
	90	56	86	0.67
STATE MODEL		56	86	0.79
CRDS AGGR.		78	100	0.86
ILLINOIS	10	89	57	0.73
	20	44	71	0.51
	30	56	29	0.24
	40	89	57	0.83
	50	78	57	0.92
	60	67	57	0.51
	70	44	57	0.52
	80	44	71	0.58
	90	56	86	0.74
STATE MODEL		100	71	0.89
CRDS AGGR.		78	57	0.81
INDIANA	10	78	71	0.90
	20	78	100	0.91
	30	89	100	0.89
	40	67	71	0.69
	50	89	100	0.83
	60	100	71	0.49
	70	67	57	0.67
	80	22	71	0.54
	90	44	71	0.54
STATE MODEL		67	86	0.82
CRDS AGGR.		89	86	0.91
REGION MODEL				
CRDS AGGR.		67	71	0.82
STATES AGGR.		56	57	0.79

Figure 9. Percent of test years (1970-1979) the direction of change from the previous year in yield as predicted by the CEAS soybean models agrees with the direction of change in the actual yield. Darker shades indicate CRDs with higher production.

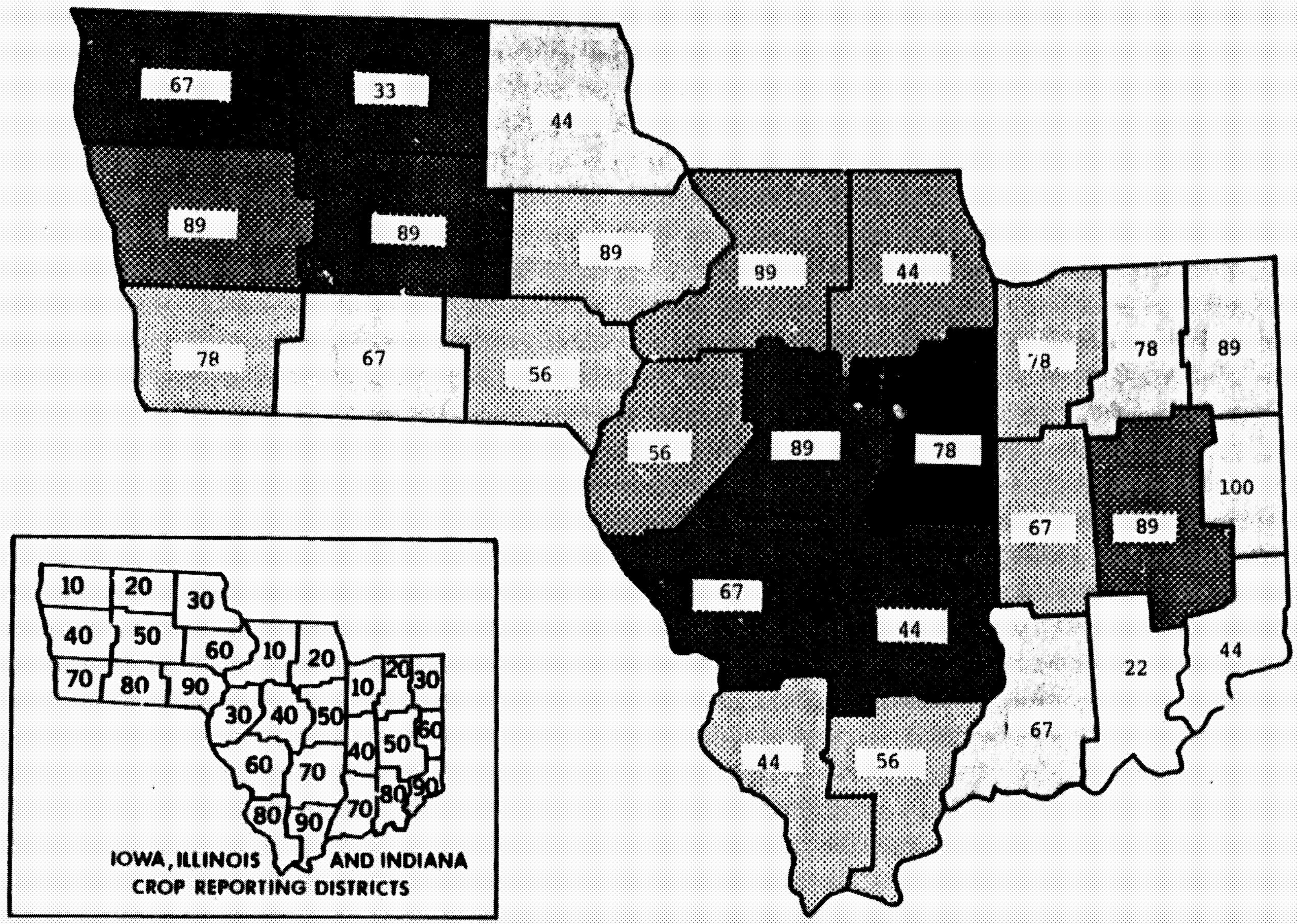


Figure 10. Percent of test years (1970-1979) the direction of change from the previous three years average yield as predicted by the CEAS soybean models agrees with the direction of change in the actual yield. Darker shades indicate CRDs with higher production.

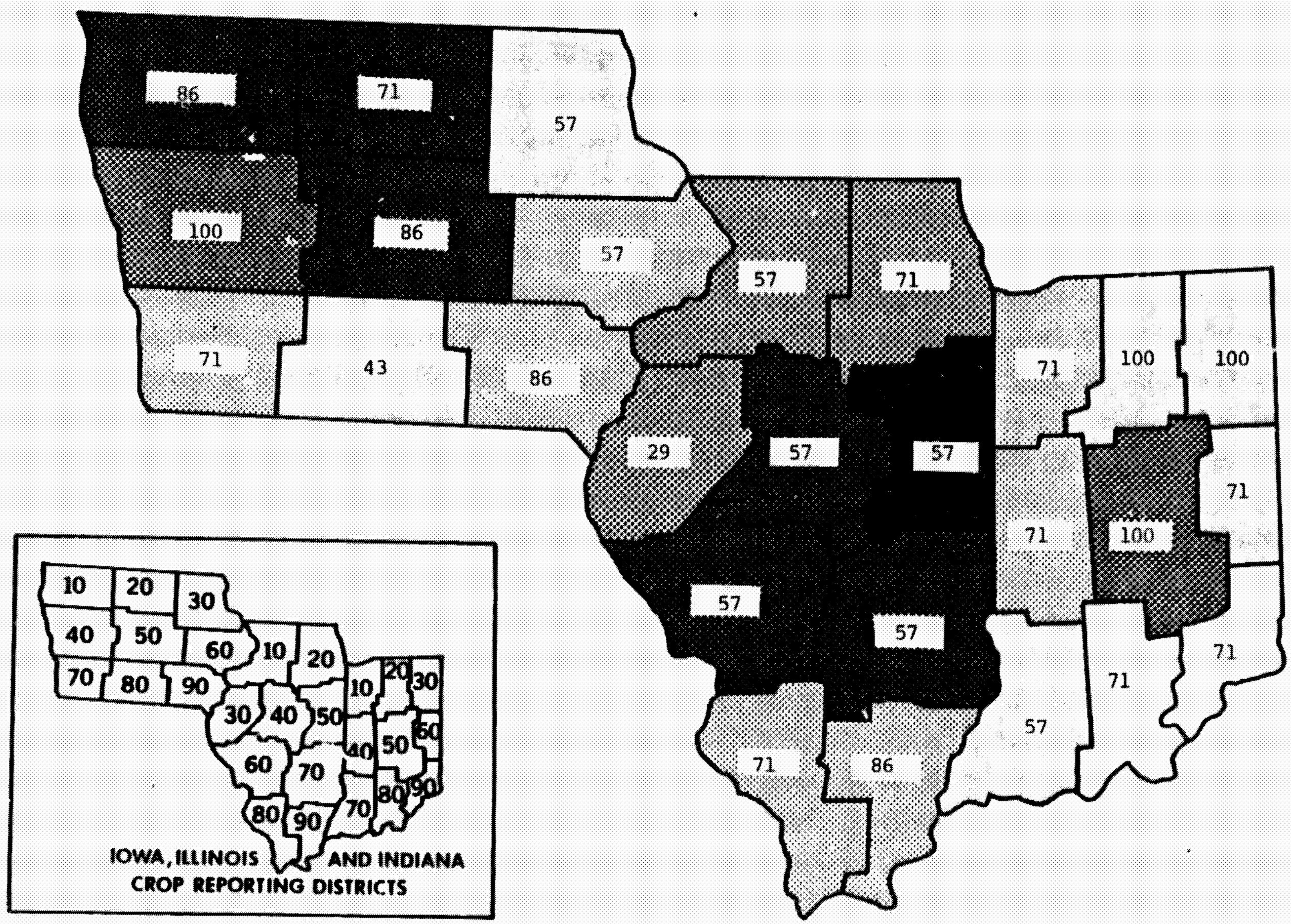
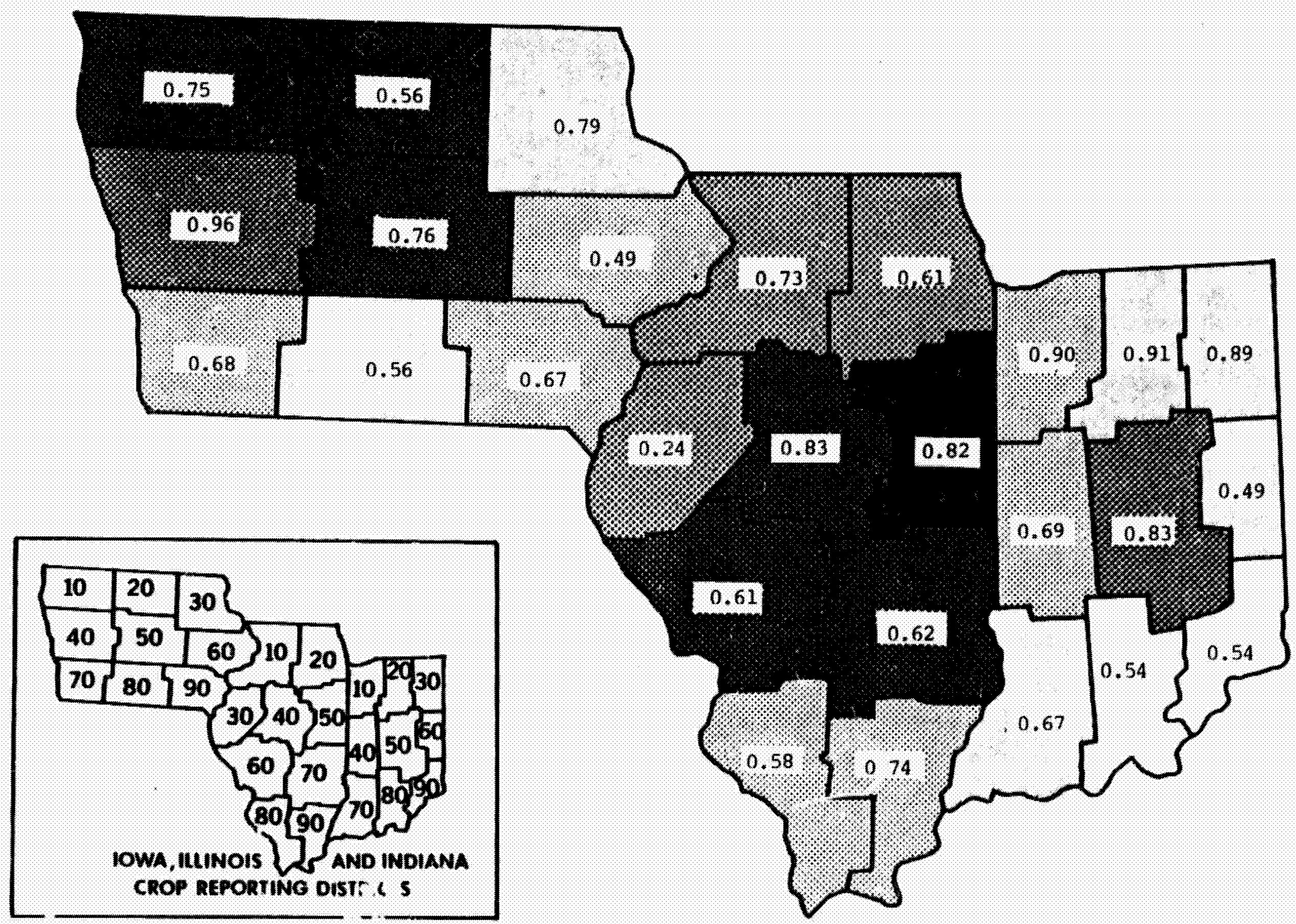


Figure 11. Pearson correlation coefficient between actual yield and yield as predicted by the CEAS soybean models for the test years (1970-1979). Darker shades indicate CRDs with higher production.



of the time are Iowa CRDs 20 and 30, Illinois CRDs 20, 70 and 80, and Indiana CRDs 80 and 90. Those models for which the direction of change is correct from the previous three years' average less than fifty percent of the time are Iowa CRD 80 and Illinois CRD 30. This is a rather large number of models which do not do well based on these indicators.

The Pearson correlation coefficients between Y and $\hat{Y}$ when squared show the percentage of the sum of squares of deviations of Y about its mean $\bar{Y}$ which can be explained by the independent variables in the model. The state and regional models show associations between 60 and 80 percent. The individual CRD models do not generally do as well.

Indicators of Base Period Precision Do Not Correspond to Precision Found During Independent Tests

Certain statistics generated from the regression analysis of the base period data are often used to provide some indication of expected yield reliability. However, these statistics only reflect how well the model describes the data used to generate the model, i.e., fit of the model, rather than how well the model can predict given new data. Therefore, it is important to compare these indicators of fit of the model to the independent indicators of yield reliability discussed in the preceding sections. In this way, one can see how these base period indicators of fit of the model do or do not correspond to independent test indicators of yield reliability.

One indicator of yield reliability, the mean square error (MSE), is the sum of squared d values ($d = \hat{Y} - Y$) for the independent test years divided by the number of test years (Table 2). The direct analogue for the model development base period is the residual mean square. The residual mean square is obtained by first generating the usual least squares prediction equation using the base period years. Then instead of predicting the yield for the following test year, yields are predicted for each of the base period years. The residual mean square is the sum of squared d values for these base period years divided by the appropriate degrees of freedom (number of years minus number of parameters estimated in fitting the model). Whereas one value of MSE is generated for each geographic area over the entire test period, a value of the residual mean square is generated for each base period corresponding to a test year for that area. The low, high, and average of the base period values for each area are given in Table 5.

The MSE values from Table 2 are repeated in Table 5. The MSE values for the independent test are larger than the highest base period residual mean square for all models except Iowa CRD 20. For this one model, the MSE is smaller than the lowest residual mean square. For all other models the precision indicated by the base period analysis is seen to be far too optimistic when compared to the independent test MSE estimates.

Another indicator of yield reliability is the correlation coefficient, r, between the observed and predicted yields for the independent test years (Table 4). It is desirable for r to be close to +1, even though it can be negative. The analogue for the model development base period is the square root of R^2, the coefficient of multiple determination. The square root of R^2 (expressed as a proportion), $R (0 \leq R \leq 1)$, may be interpreted as the correlation between observed and predicted values for the base period years. The low, high, and average values of R for each geographic area are given in Table 6. The Pearson correlation coefficients are also repeated in Table 6 in the column "Independent Correlation Coefficients."

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TABLE 5
RESIDUAL MEAN SQUARE AS AN
INDICATOR OF THE FIT OF THE MODEL
BASED ON THE MODEL DEVELOPMENT BASE PERIOD

CEAS MODEL - SOYBEANS
IOWA, ILLINOIS, INDIANA

STATE	CRD	BASE PERIOD RESIDUAL MEAN SQUARE LOW	HIGH	AVERAGE	INDEPENDENT TEST MSE
IOWA	10	1.44	2.20	1.94	4.24
	20	1.59	1.89	1.75	1.57
	30	1.10	1.41	1.26	2.07
	40	0.37	0.42	0.40	0.70
	50	0.97	1.45	1.20	2.48
	60	1.01	1.57	1.26	5.19
	70	1.26	1.64	1.39	1.98
	80	2.42	3.03	2.74	4.89
	90	1.15	1.38	1.27	3.21
STATE MODEL		0.77	1.05	0.87	2.21
ILLINOIS	10	1.08	1.56	1.35	5.05
	20	1.51	2.09	1.77	5.54
	30	0.90	1.67	1.29	6.95
	40	1.31	2.04	1.65	5.19
	50	0.94	1.29	1.12	2.97
	60	1.11	1.46	1.29	4.52
	70	1.40	1.88	1.62	5.05
	80	2.12	2.49	2.27	4.44
	90	1.30	1.59	1.39	3.32
STATE MODEL		0.62	0.88	0.75	2.45
INDIANA	10	1.10	1.34	1.19	2.05
	20	0.91	1.03	0.97	1.68
	30	1.51	1.69	1.61	2.44
	40	1.45	1.97	1.67	4.05
	50	1.22	1.44	1.31	2.47
	60	1.13	1.41	1.28	3.04
	70	0.74	0.95	0.81	3.02
	80	0.99	1.29	1.10	3.25
	90	1.86	2.06	1.95	3.22
STATE MODEL		0.57	0.80	0.68	1.87

TABLE 6
CORRELATION BETWEEN OBSERVED AND PREDICTED YIELDS AS AN INDICATOR OF THE FIT OF THE MODEL BASED ON THE MODEL DEVELOPMENT BASE PERIOD

CEAS MODEL - SOYBEANS
IOWA, ILLINOIS, INDIANA

TEST STATE	CRD	BASE PERIOD CORRELATION COEF. LOW	HIGH	AVERAGE	INDEPENDENT CORR. COEF.
IOWA	10	0.92	0.95	0.93	0.75
	20	0.90	0.95	0.92	0.56
	30	0.93	0.96	0.95	0.79
	40	0.98	0.99	0.99	0.96
	50	0.95	0.97	0.95	0.76
	60	0.94	0.96	0.95	0.49
	70	0.95	0.96	0.96	0.58
	80	0.82	0.89	0.86	0.56
	90	0.92	0.95	0.93	0.57
STATE MODEL		0.96	0.97	0.96	0.79
ILLINOIS	10	0.95	0.97	0.96	0.73
	20	0.92	0.93	0.93	0.61
	30	0.95	0.97	0.96	0.24
	40	0.94	0.97	0.96	0.83
	50	0.96	0.97	0.96	0.82
	60	0.96	0.97	0.97	0.61
	70	0.92	0.94	0.93	0.62
	80	0.93	0.94	0.94	0.58
	90	0.94	0.95	0.95	0.74
STATE MODEL		0.97	0.98	0.97	0.89
INDIANA	10	0.95	0.96	0.96	0.90
	20	0.95	0.97	0.96	0.91
	30	0.90	0.93	0.92	0.89
	40	0.93	0.95	0.94	0.69
	50	0.95	0.96	0.96	0.83
	60	0.94	0.95	0.95	0.49
	70	0.97	0.98	0.98	0.67
	80	0.96	0.97	0.96	0.54
	90	0.94	0.95	0.94	0.54
STATE MODEL		0.97	0.98	0.97	0.92

The lowest base period correlation coefficients are all larger than the independent correlation coefficients, confirming that the levels of R or R^2 for a model development base period are of no value in indicating the independent performance of these models.

Models are Objective

To predict the yield for a future year, the value for trend and any weather-related variables in the models would be calculated and used with the regression coefficients derived when the models were developed. This would be a completely objective process.

There are four subjective specifications in the model. In order to calculate the values of the RATIO variable, the user must sepcify the beginning moisture in the surface layer, the available water capacity in the surface layer, the beginning moisture in the underlying layer, and the available water capacity in the underlying layer.

The models would probably be updated as new data was collected, and new trend terms might be needed. Because the methodology used in developing the models is not well specified, it would be difficult to duplicate the process.

Models Show General Consistency With Scientific Knowledge

The model developer used three types of variables: (1) year, as a surrogate for technology, (2) derived meteorological variables, such as temperature expressed as deviations from normal, and (3) derived agroclimatic variables, for example, the difference between precipitation and potential evapotranspiration.

Trend terms are an important component of trend and monthly weather data models. Usually, they are the first terms selected by the stepwise procedure and account for more than half of the total variation in yield explained by the model. Also, the specification of trend determines the residuals of trend which are assumed to be dependent on the meteorological and agroclimatic variables. Therefore, if trend is improperly handled in a model, results may be substantially affected.

For the Iowa and Illinois models evaluated, changes in yield due to technology are assumed to be continuous piecewise linear functions of time (year). Piecewise functions allow the year-to-year contribution to yield from technology and other non-weather factors to be different over various time periods. In fact, the contribution may be zero over some portions of time. A period of such flat trend indicates no increases (or decreases) in yield due to technology (or non-weather) factors. As long as one is not able to consider the various component parts of technology, this form of the model seems reasonable. However, it does not allow for discontinuities in the yield level due to sudden shifts in technology.

Two trend terms were used for Iowa and for Illinois, and one term for Indiana. TREND 1 for Iowa increased from 1955 to 1960 and TREND 2 for 1961 to 1978. TREND 1 for Illinois increased from 1932 to 1960 and TREND 2 from 1961 to 1978. The single TREND term for Indiana increased from 1937 to 1978. No indication is given as to what trend terms should be used in the future. No scientific evidence is proposed to account for the change-over points in trend, or the differences in trend between states.

In terms of consistency with scientific knowledge, it would be most desirable not to have to use year as a surrogate for technology and/or other non-weather factors. However, if it must be used, the change-over points should be chosen objectively and in such a way that scientific evidence could be used as supporting evidence. Even if change-over points must be subjectively determined, they should be clearly linked to available scientific evidence of actual changes in technology and other non-weather factors. This would also allow some guidelines to be developed for the choice of change-over points when model re-development occurs in future years or in other geographic areas.

As mentioned previously, if technological improvements in crop yields are modeled by a trend term based on year, the manner in which trend appears in the model can have a large impact on yield estimates and forecasts. It is not at all clear that entering trend and weather as distinct variables in a single regression equation clearly separates the impact of weather and non-weather influences on yield. More research needs to be done on alternate methods of distinguishing the effects of weather and technology.

This CEAS model uses monthly weather values. There is little correspondence between the beginning and ending of a calendar month and the beginning and ending stages of development for soybean plants (and its changing temperature and moisture requirements), especially since plants do not begin development stages at the same time each year.

Another problem in using a single monthly weather value for a CRD or state is the underlying assumption that each year the value is representative of the entire area for the entire month. In one year the value may be more representative of the conditions in one part of the area or in one part of the month and in another year the same value may be more representative of another area or part of the month. Variables involving rainfall could be particularly affected by these dissimilarities from year-to-year. Of course these comments apply to any model constructed from variables of this type, not just the CEAS models.

Monthly meteorological variables available on a climatic division basis (corresponding to a crop reporting district) are average temperature and total precipitation. The monthly precipitation values are also summed to obtain cumulative precipitation terms. The average value of these monthly meteorological variables is subtracted from its value for the month for deviations from normal values.

Terms are selected for inclusion in the models from these various derived meteorological variables using a stepwise procedure along with subjective judgments. Use of the stepwise procedure for CRD models frequently leads to the inclusion of a variable in a particular CRD but not in any of the surrounding CRDs, which might be difficult to support scientifically.

Most of the meteorological variables are considered as deviations from normal, both linear and quadratic. The implication of squared deviations from normal precipitation is that a large deviation from normal, in either a positive or negative direction has an equal impact on the yield. Evidence is not given to support this assumption.

The model for Iowa CRD 30 uses the predictor "temperature in June." It is rather surprising that "deviations from normal temperature in June" is not used instead to correspond with the other models.

Several Iowa and Illinois models use the meteorological variable "cumulative precipitation from the end of the previous growing season (September)" extending to either April or May of the current year. All have negative coefficients, reducing the yield if the cumulative precipitation is high. This would seem plausible only if planting were delayed as a consequence. However, an increased yield when cumulative precipitation is low would only due to earliness of planting. If cumulative precipitation fell below a critical level, yield would be reduced.

The model report states that soil temperature is important during planting, germination, emergence, and early vegetative growth. The deviations from normal temperature (DFNT) for May and June could be used for these factors, although this is not stated in the report. These variables are included in several of the models. Iowa CRD 40 has a negative coefficient for DFNT (May), but the rest have positive coefficients (ranging from 0.1 to 0.6) indicating that colder temperatures would decrease yield.

Two Iowa CRD models (70 and 80) include a DFNT (April) term, both with negative coefficients. These negative coefficients are not what would be expected based on scientific considerations.

A second critical period in soybean development proposed by the model report occurs during the flowering stage. High temperatures and moisture stress would decrease yield. For the months of July and August, deviations from normal precipitation (DFNP), squared DFNP (SDFNP), precipitation minus monthly potential evapotranspiration (DEF), actual evapotranspiration divided by climatically-appropriate evapotranspiration (RATIO), and DFNT could be used for these factors.

RATIO for July or August are used in many of the models. The signs of the coefficients are all positive, indicating that the less the crop-available moisture, the lower the yield.

DEF (P - PET) for July or August are also used in several models. Again, the signs of the coefficients are positive, indicating that aridity will decrease yield.

SDFNP for July or August are also popular for inclusion in models. The signs of these coefficients are almost exclusively negative, indicating that a large departure from normal precipitation (positive or negative) will decrease yield. Indiana CRD 20, however, has a positive coefficient for SDFNP (August), which would not be appropriate.

Several models included DFNP for July or August. The coefficients for these variables are positive except for Indiana CRD 60. This would imply that a lack of rain would lead to a lower yield.

DFNT for July and August were included in only 3 CRD models. Coefficients for Indiana CRD 30 and Iowa CRD 50 are both positive. Indiana CRD 80 has a negative value. In order for a high temperature to produce a decrease in yield, the coefficients should be negative.

The final critical period mentioned in the report is the period from beginning podfill to end of flowering, when water stress is especially detrimental.

DFNT for September was used in five of the Iowa models including Iowa state model. The coefficients are all positive indicating that high temperature is related to high yield, perhaps related to a reduced incidence of frost damage.

RATIO for September would be a better measure of water stress and was used in several of the models. The coefficients are all positive, showing that increased crop available moisture increased yield.

Other variables are included in the models, probably for increased predictability, but no scientific reasons for their inclusion are stated.

In order to calculate the agroclimatic variables, PET and a soil moisture budget are estimated. ET is estimated using PET, P, and the contents and capacity of the soil moisture budget. Thornwaite's (1948) procedure is used to calculate monthly PET. The consideration of other procedures is not mentioned. Running a soil moisture budget on a monthly basis is a difficult task. This is mainly because runoff cannot be determined accurately. An available water capacity of ten inches (254 mm) is assumed for all CRDs and three states. Palmer (1965) recommends ten inches as a reasonable figure for Central Iowa. He assumes six to eight inches is more appropriate for western Kansas. No scientific evidence is presented in the present case to justify the ten inch budget in Illinois and Indiana and its uniform value in every CRD.

Values of the meteorological deviation from normal and agroclimatic variables to be used in the state models are computed as weighted averages of the values used in the CRD models. An alternative method of calculating then would be to compute the weighted average of the basic meteorological variables, monthly average temperature and total precipitation, and then calculate the variables at the state level in the same manner as they were computed at the CRD level. No scientific evidence is presented to show a preference for performing the aggregation one way or the other. There will be a difference in the results of the two methods due to nonlinearity.

Finally, one would like to see the use of a variety of methods for variable selection and parameter estimation. In the field of regression analysis, increasing use is being made of new diagnostic, robust estimation and variable selection techniques. The use of these new techniques does not guarantee better models but should, at least, lead to a better understanding of the limitations of the models.

Model Re-Development Would Be Required to Predict Other Than CRD and State Yields

In theory, a CEAS trend and monthly weather data model could be developed for any geographic area and for any level of detail as long as historic values of year, yield, and monthly average temperature and total precipitation were available. However, the complete model development process would have to be followed in order to develop models for other than CRD or state geographic subdivisions in Iowa, Illinois, and Indiana or for areas outside these states. So the models are only adequate for those geographic areas, subdivisions, and time periods for which they have been developed.

Trend and Monthly Weather Data Models Are Not Costly to Operate

Operational costs of running these models through a growing season are moderate. The monthly weather data (average temperature and total rainfall) obtained on a timely basis is currently prepared for other users on a routine basis, so that conceptually the cost could be shared. All that is required to obtain the yield estimates is to have someone responsible for acquiring the weather data and performing the regression equation calculations.

The more expensive part of the process is the maintenance of the historic agricultural and meteorological data bases and the re-development of models as required. The maintenance of the data bases requires the part-time efforts of persons familiar with meteorological data, agricultural data, and the computer system being used. The re-development of the models in future years, incorporating more recent yield and weather data, would require the skills of a person familiar with statistical regression methodology and agronomic modeling using meteorological variables.

It is difficult to say how expensive it would be to develop a model for another geographic area. The availability and form of the weather and yield data would be the determining factor.

Timely Estimates Can Be Made Using Approximated Weather Data

Truncated models were developed for each CRD and state using weather data available through each of the months of March and September. In several cases no significant predictor variable was found, and no model was developed. These truncations were not evaluated in this paper, but the methodology used in the model development report (Motha, 1980) could be used to estimate yield during the year.

It takes at least three months after the end of a month to obtain that month's average temperature and total precipitation for the climatic divisions from the National Climatic Center in Asheville, North Carolina. However, estimates of these climatic division values can be prepared earlier. These weather data approximations could be used in the regression equations to obtain yield estimates in the first week of the month following the month to which the weather data pertains. The yield estimate will not change if the model for a particular month is the same as for the previous month.

Models Are Easy to Understand and Use

The variables contained in these trend and monthly weather data models for soybean yield estimation are fairly simple and easy to understand. A computer program would normally be used to calculate at least the values of the stress variables. The contents of the soil moisture budget would need to be saved from the previous year unless it could be assumed that the budget was filled to capacity over the winter months. It may be confusing to users to have three different kinds of similarly defined stress variables appearing in the models for various CRDs. Also, the user might expect large values of a stress variable to indicate more stress instead of less. Interpretation of some coefficients may be difficult in models which include for both precipitation as a deviation from long term average and as part of a stress variable for the same month.

Standard Errors of Prediction Provide Poor Current Measures of Modeled Yield Reliability

Table 7 shows the Spearman correlation coefficients between the estimated standard error of a predicted yield value ($s\hat{y}$) and the absolute value of the difference between the predicted and actual yield ($|d|$) for CRD and state models. Figure 12 also shows the CRD values.

For eight of the 27 CRD models and Iowa CRD aggregated model, the correlation coefficient is negative. For most of the other models, the coefficients are very low. The largest positive coefficient is 0.64 for Indiana CRD 80. Based on the correlation coefficients, one can conclude that $s\hat{y}$ does not provide a good measure of the closeness of the predicted values to the actual yield values. That is, the accuracy of a predicted yield cannot be reliably judged using $s\hat{y}$.

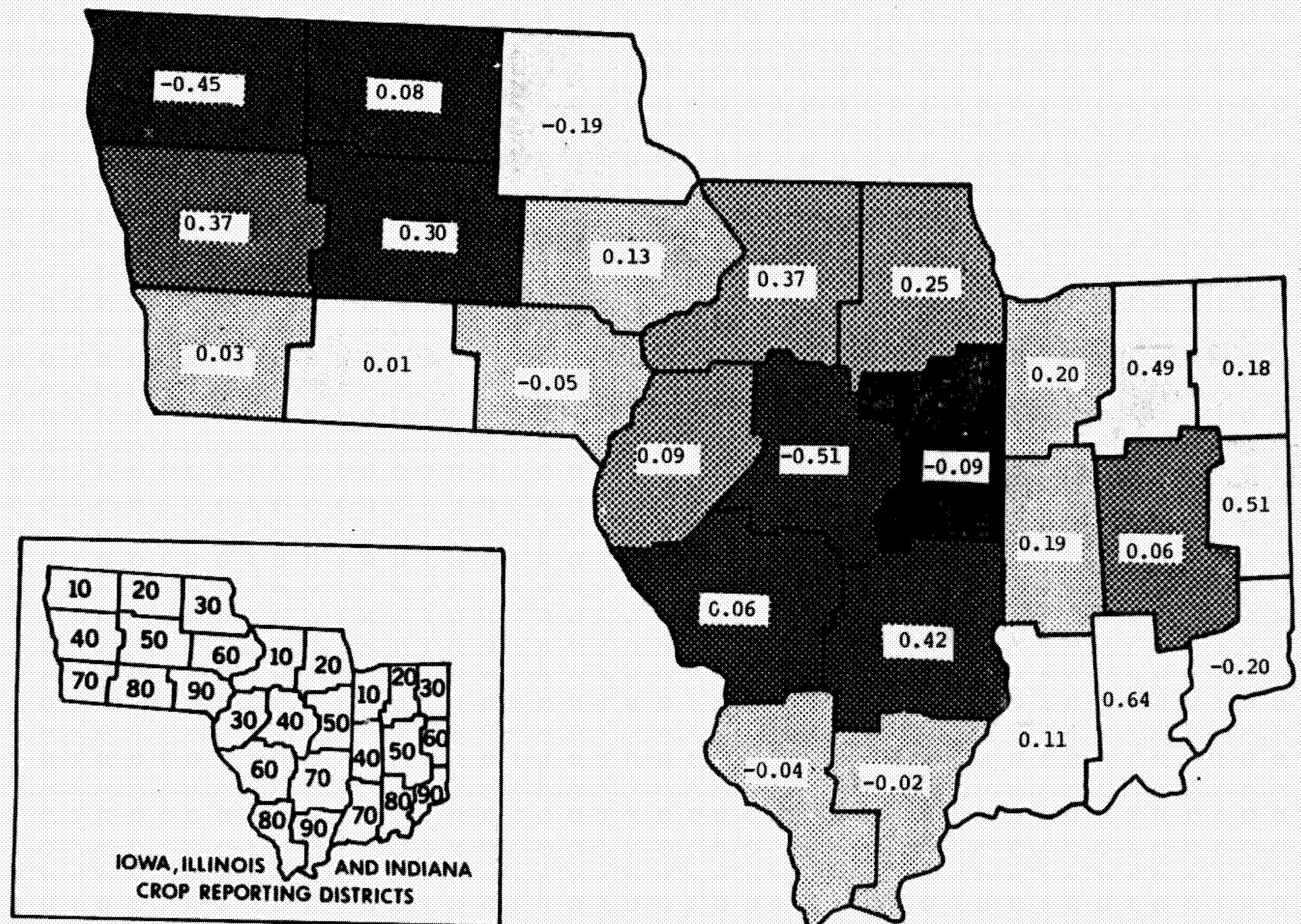
TABLE 7
CURRENT INDICATION OF
MODELED YIELD RELIABILITY

AGREEMENT BETWEEN BASE PERIOD PREDICTED
AND TEST YEAR ACTUAL ACCURACY

CEAS MODEL - SOYBEANS
IOWA, ILLINOIS, INDIANA

STATE	CRD	SPEARMAN CORRELATION COEF.
IOWA	10	-0.45
	20	0.08
	30	-0.19
	40	0.37
	50	0.30
	60	0.13
	70	0.03
	80	0.01
	90	-0.05
STATE MODEL		0.44
ILLINOIS	10	0.37
	20	0.25
	30	0.09
	40	-0.51
	50	-0.09
	60	0.06
	70	0.42
	80	-0.04
	90	-0.02
STATE MODEL		0.11
INDIANA	10	0.20
	20	0.49
	30	0.18
	40	0.19
	50	0.06
	60	0.51
	70	0.11
	80	0.64
	90	-0.20
STATE MODEL		0.27

Figure 12. Spearman correlation coefficient between the estimate of the standard error of a predicted value from the CEAS soybean base period model and the absolute value of the differenc between the predicted and actual yield in the test years (1970-1979). Darker shades indicate CRDs with higher production.



CONCLUSIONS

At the state level, the bias of the models as estimated over the ten test years, is less than half a quintal/hectare. The standard deviation is between one and two quintals/hectare. The squared Pearson correlation coefficients show that the variables used in the state models can be used to account for between 60 and 80 percent of the yearly variation in yields.

The state models are consistently better than the CRD models. In particular, the model for Illinois CRD 30 seems to be poor as measured by several of the criteria. The model standard errors of prediction do not provide a useful current measure of modeled yield reliability.

The model is objective, but due to inadequate documentation in the initial report, it is difficult to assess the subjectivity that would be involved in a redevelopment of the model. The models are adequate in terms of coverage, and they show general consistency with scientific knowledge.

The models are not costly to operate, but redevelopment costs cannot be estimated. Timely yield forecasts can be made during the growing season using the truncated models. The models are easy to understand and use.

REFERENCES

Motha, Raymond P., 1980. Soybean Models for Iowa, Illinois, and Indiana. NOAA/CEAS, Models Branch, Columbia, MO.

Palmer, Wayne C., 1965. Meteorological Drought. Research Paper No. 45, U.S. Department of Commerce, Washington, D.C.

Thornthwaite, C.W., 1948. An Approach Toward a Rational Classification of Climate. Geographical Review, 38: 55-94.

Wilson, Wendell W., Barnett, Thomas L., LeDuc, Sharon K., Warren, Fred B., 1980. Crop Yield Model Test and Evaluation Criteria, AgRISTARS Yield Model Development Project, Document YMD-1-1-2, (80-2.1).

APPENDIX A

Brief Description of Growing Conditions for Soybeans in Bootstrap Test Years for Iowa*

Year	
1970	Yield same as 1969 (record up to this point). Production up 4%. Planting well ahead of average. Dry conditions cause field losses during harvest. A small crop insurance loss claimed due to drought.
1971	Yield same as 1970. Production down 3%. Planting well ahead of average. Cool, dry weather during May slows crop development. June rain and warm weather help crops to make normal progress. Dry conditions during midsummer stress soybeans. Early harvest Small crop insurance claims from hail and drought.
1972	Yield up 11%. Production up 21%. Rains delay planting. Season noteworthy for hail losses and flood losses. 24 tornadoes during season. Harvest season one of worst on record. Small insurance claims for hail and excess moisture.
1973	Yield down 6%. Production up 22%. Planting slow due to rain. Warmest year (tied with 1964) since 1954. Wettest year since 1902. Last 2 years are the wettest of all 101 years of Iowa weather records. Growing season cooler than normal but longer. Harvest season delayed due to rain but one of finest. Small crop insurance losses due to excess moisture.
1974	Yield down 18%. Production down 24%. Heavy rains in May and June. Hot, dry weather in late June and July. Unusually early frosts in September. Erosion and flooding worst in years in the eastern part of the state. Small crop insurance losses due to hail. Corsoy is major soybean variety, followed by Amsoy and Wayne.

APPENDIX A

<u>Year</u>

1975 Yield up 21%.
Production up 19%.
Frequent rains delay planting.
Late June rains in the central region cause flooding.
Six consecutive weeks of hot, dry weather in July and August.
Rains in late August and September too late for some soybean plants.
Ideal harvest weather.
Small insurance claims due to drought.
Wayne moves ahead of Amsoy as second most popular variety.

1976 Yield down 9%.
Production down 16%.
Dry mid-May for good planting.
June and July warm and dry.
Hot, dry weather later slows development.
Early harvest due to weather.
Small insurance loss due to drought.
Wells repaces Amsoy as third most popular variety.

1977 Yield up 15%.
Production up 26%.
Coldest winter in Iowa history.
Herbicide damage causes some replanting.
Planted second largest acreages on record.
Minor weed control problems.
Grasshopper damage.
Soybean crop stress in June, July.
Cool, wet weather delays harvest.
Insurance claims due to drought.
Amsoy again becomes third most popular variety.

1978 Yield up 6%.
Production up 13% (a new record high).
Second most severe winter in 20th century.
Cold, wet spring delayed planting.
Soybean acreage planted second highest in history.
Warm, muggy June and July - excellent growing season.
Relatively insect + and disease free.
Above average moisture in July facilitates crop growth.
Warm August; some CRDS had a 3 week drought with rain at month's end.
Hot, dry weather early fall promotes crop maturity.
Late September cooler and wetter.
Excellent harvest weather.
Small insurance claims due to hail.
Corsoy remains most popular variety followed by Wells and Williams.

APPENDIX A

Year

1979 Yield same as 1978.
Production up 8% (record high).
One of worst winters on record.
Wet, cold soils delay planting but later progressed rapidly.
Harvest ahead of schedule.
Small insurance claims for hail.

*References

Feyerherm, Arlin M., July 1, 1981. Identification of Social and Natural Episodes that Impact Crop Yields, Quarterly Progress Report. Kansas State University, Manhattan, KS.

Iowa Crop and Livestock Reporting Service. Iowa Agricultural Statistics, 1975-1979, 1981. Des Moines, Iowa.

Iowa Crop and Livestock Reporting Service. Weather and Field Crops from Planting to Harvest, 1970, 1971, 1972, 1973, 1974, 1979. Des Moines, Iowa.

APPENDIX A

Brief Description of Crowing Conditions for Soybeans in Bootstrap Test Years for Illinois*

Year

1970 Yield down 7½%, record harvested area up 2%.
Heavy April rains in North and Central delayed planting.
Crops in good condition most of season.
September rains cause late harvest.
Dominant variety is Wayne, followed by Amsoy.

1971 Yield up 6%, record harvested area up 5%.
Record production up 12%.
Planting over early.
Lack of extremes in temperature bring ideal growing conditions.
Some moisture stress.
Harvest ahead of normal.

1972 Yield up 4½%, production up 10%, harvested area up 5%; all are new state records.
Planting normal.
Dry June weather.
Summer moisture adequate.
Cool temperatures all summer.
Rain slowed harvest.
41% of planted area sown in 37-38" row widths.

1973 Yield down 7%.
Record production up 8% and record harvested area up 19%.
Heavy spring rains delay planting.
Growing season temperatures normal with above normal precipitation through July.
Harvest on time.

1974 Yield down 24%, production down 28% (lowest since 1967).
Heavy spring rains and late freeze delay planting to very late.
Cool tempeatures most of summer, dry late summer, and then early September rains and freeze delay harvest.
Wayne still dominant variety with Williams and Amsoy tied for second.

1975 Record yield up 50%.
Record production up 46%, harvested area down 3%.
Planting completed early.
Growing season temperatures normal and precipitation above normal.
Dry, warm fall weather allows harvest to finish well ahead of normal.

APPENDIX A

Year

1976 Yield down 8%, production down 17%, harvested area down 9% (lowest since 1972).
Planting ahead of normal.
Growing season mostly cool and dry; precipitation 10" below normal (especially NW, NE and West).
Harvest completed early.
Williams now dominant variety, Wayne drops to second.
42% of planted area sown in 27" - 30" row widths.

1977 Record yield up 15%, record production up 35%.
Harvested area up 17%.
Planting ahead of normal.
Growing season generally cool and wet.
Heavy fall precipitation reduces quality and delays harvest.

1978 Yield down 12%, production down 8½%, record harvested area up 4%.
Planting extremely delayed by heavy rains.
Growing season generally cool and dry with temperatures 3° below normal.
Harvest normal to early.
Williams dominant variety with Amsoy second.
46% of planted area in 27" - 30" row widths.

1979 Yield up 15%, production up 21%, harvested area up 6%; all are new state records.
Planting starts late but finishes early.
Weather during growing season slightly cool with normal precipitation.
W, C, and SW had slightly less moisture.
Normal to early harvest.

*References

Illinois Cooperative Crop Reporting Service. Illinois Agricultural Statistics, 1971-1980. Bulletins 71-1 to 80-1. Springfield, Illinois.

APPENDIX A

Brief Description of Growing Conditions for Soybeans in Bootstrap Test Years for Indiana

Year	
1970	Yield and production down 4%. Harvested area down 1%. Wet soils hindered planting. Heavy August and September rains also delayed harvest.
1971	Yield up 6%, production up 9%. Harvested area up 3%; all are new state records. Dry cool spring with mild drought. Planting completed early. Harvest also ahead of schedule.
1972	Yield down 11%, production down 3%. Record harvested area up 9%. Planting occured for normal schedule. During season South was dry, North had excess moisture. Harvest far behind schedule - only 60% completed by end of year.
1973	Yield up 7%, record production up 24%. Record harvested area up 16%. Surplus spring moisture slows planting. Harvest on normal schedule.
1974	Yield down 26%, production down 30%. Harvested area down 9%. Lowest yield and production since 1967. Heavy May rains slow planting. Hot, dry July. Extremely early fall freeze catches 40% of crop still in immature stages.
1975	Record yield up 32%, production up 25%. Harvested area down 7%. Excellent early planting weather. Growing season conditions bring abundant rainfall and optimum temperatures. Early fall weather dry and sunny, allowing for an early harvest.
1976	Record yield up 1%, production down 8%. Harvested area down 10%. Early planting conditions most favorable in several years. Springs and early summer cool and dry. Some moisture stress in late summer. Harvest underway early. Williams is dominant variety, followed by Amsoy.

APPENDIX A

Year

1977 Record yield up 8%, record production up 29%.
Harvested area up 18%.
Weather extremes occurred over state.
Early summer had some drought.
Harvest delayed by wet, cool weather.
Williams still dominant variety but only by small percentage over Amsoy.

1978 Yield down 7%, production down 1%.
Harvested area up 1%.
Wet fields slowed early planting
Growth slow over early summer.
Excellent harvest conditions.
Williams dominant variety.

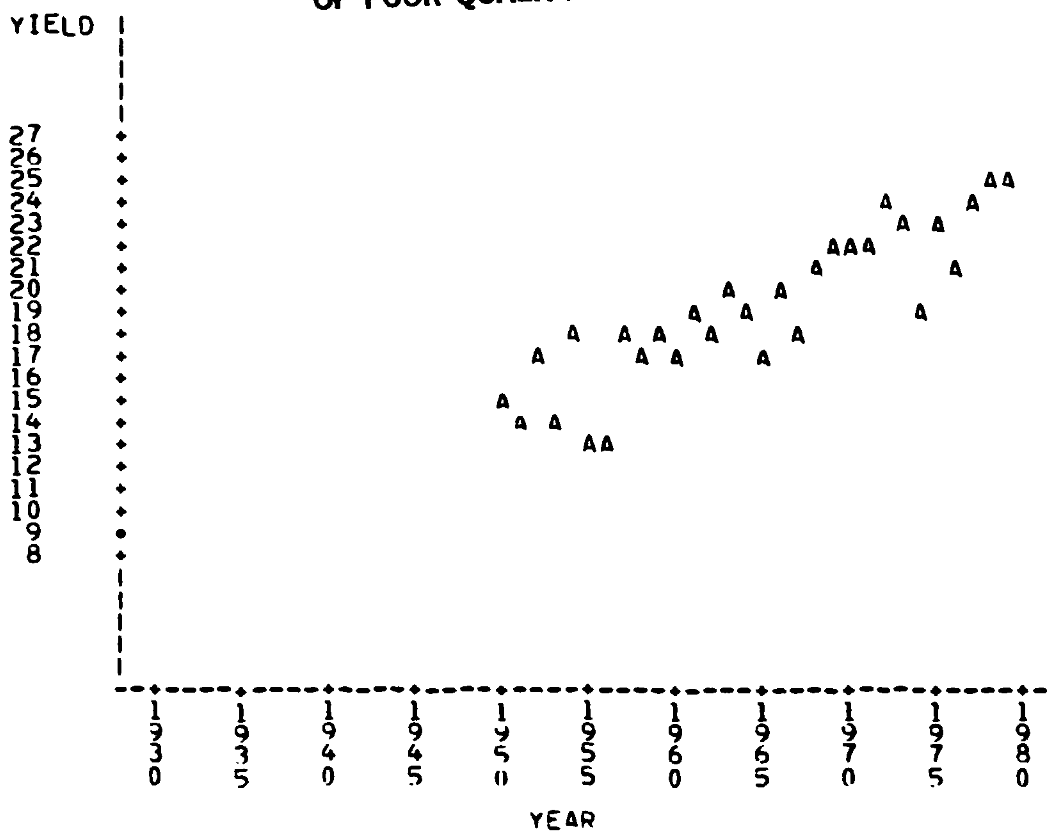
1979 Yield up 4%, record production up 10%.
Record harvested area up 5%.
Cold wintery early spring weather slows planting.
Summer rains also heavy in parts (10" - 16").
Cool autumn weather allows for early maturity and harvest.

*References

Indiana Crop and Livestock Reporting Service.
Annual Crop and Livestock Summary, 1974-1980.
West Lafayette, Indiana.

United States Department of Commerce NOAA; United States Department of Agriculture, SRS. Weekly Weather and Crop Bulletin, Volumes 57-60.

Appendix B
Plot of Actual Soybean Yields for years 1950-1979
for Iowa



Appendix B
Plot of Actual Soybean Yields for years 1931-1979
for Illinois

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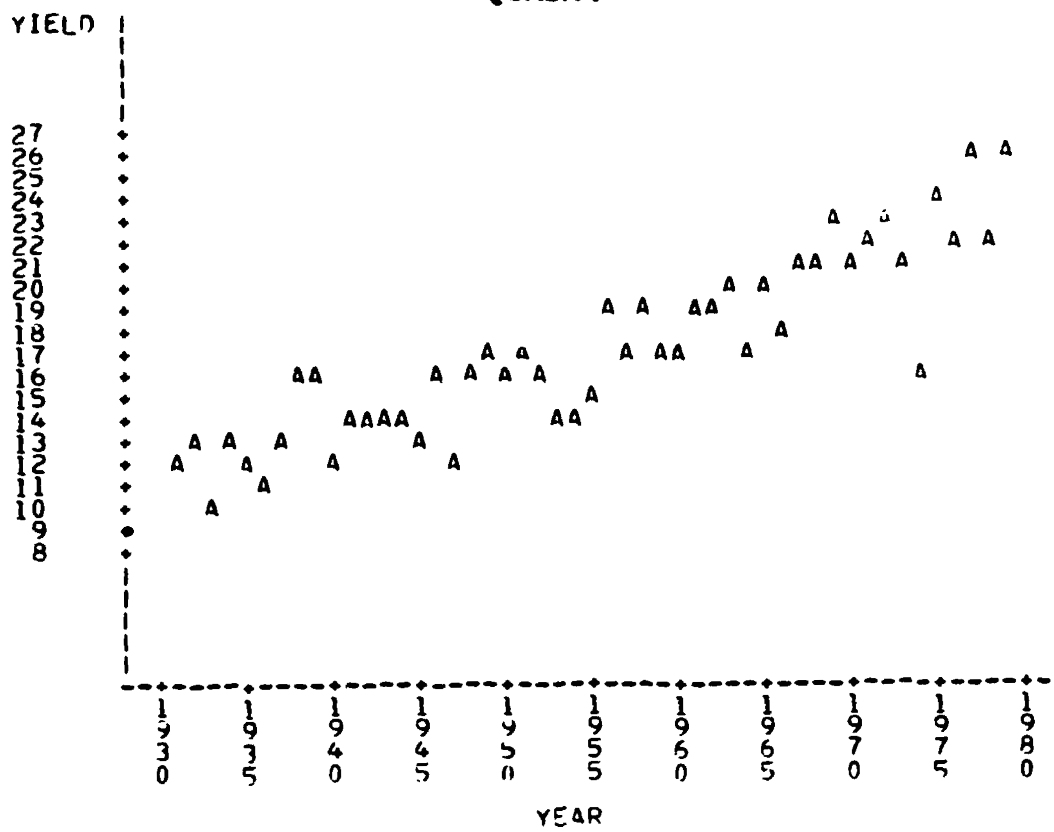
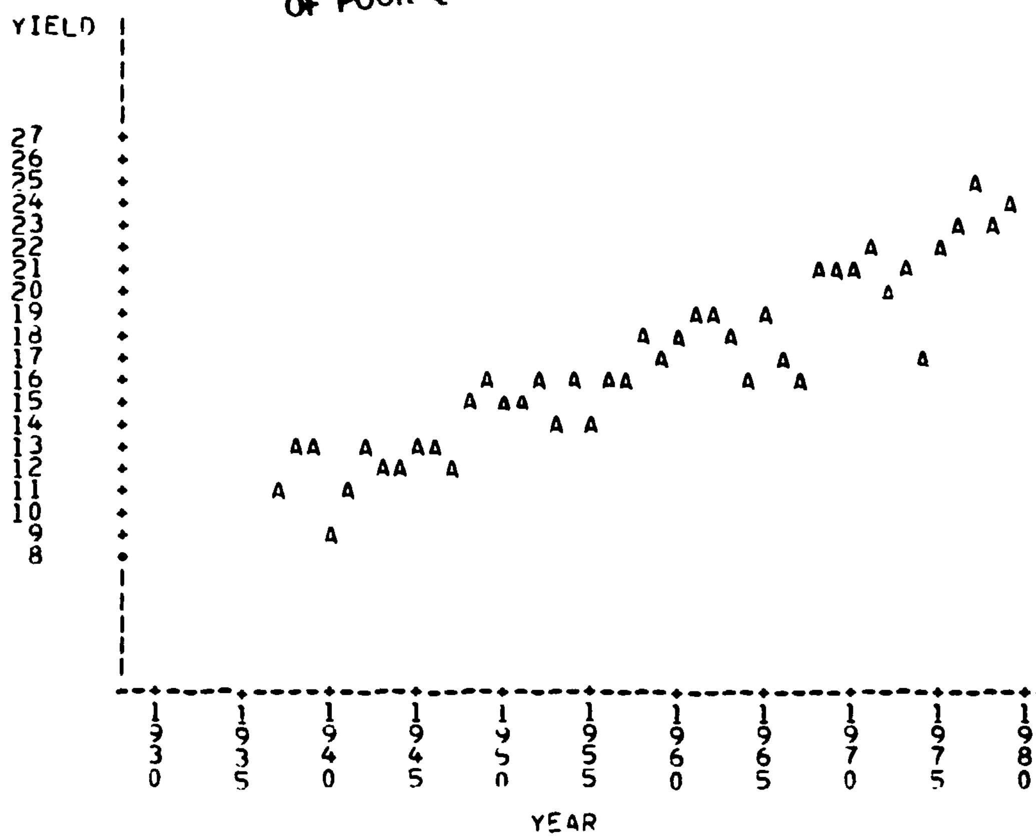


Appendix B
Plot of Actual Soybean Yields
for Years 1937-1979 for Indiana



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APPENDIX C
BOOTSTRAP TEST RESULTS
FOR SOYBEAN YIELDS IN
IOWA, ILLINOIS, AND INDIANA
USING A CEAS MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
IOWA	10	1970	19.1	20.1	1.0	5.2	1.70
		1971	21.6	20.3	-1.3	-6.0	1.51
		1972	25.3	22.0	-3.3	-13.0	1.42
		1973	24.7	23.1	-1.6	-6.5	1.55
		1974	19.8	23.4	3.6	18.2	1.60
		1975	24.1	23.0	-1.1	-4.5	1.70
		1976	20.0	20.3	0.3	1.5	1.92
		1977	26.3	26.4	0.1	0.4	1.68
		1978	26.9	29.4	2.5	9.3	1.83
		1979	24.9	27.3	2.4	9.6	1.50
	20	1970	22.2	22.2	0.0	0.0	1.71
		1971	21.4	23.1	1.7	7.9	1.69
		1972	23.4	22.0	-1.4	-6.0	1.57
		1973	22.8	23.5	0.7	3.1	1.55
		1974	19.4	22.0	2.6	13.4	1.63
		1975	23.2	21.7	-1.5	-6.5	1.53
		1976	21.7	21.8	.1	0.5	1.75
		1977	24.6	24.6	0.0	0.0	1.54
		1978	24.3	24.7	0.4	1.6	1.47
		1979	23.6	22.5	-1.1	-4.7	1.73
	30	1970	21.8	20.1	-1.7	-7.8	1.31
		1971	19.1	20.8	1.7	8.9	1.42
		1972	22.0	19.8	-2.2	-10.0	1.29
		1973	21.0	19.2	-1.8	-8.5	1.49
		1974	18.3	20.3	2.0	10.9	1.39
		1975	20.4	20.2	-0.2	-1.0	1.51
		1976	19.8	19.6	-0.2	-1.0	1.59
		1977	25.0	23.7	-1.3	-5.2	1.44
		1978	24.6	23.6	-1.0	-4.1	1.29
		1979	24.1	23.9	-0.2	-0.8	1.25
	40	1970	19.3	18.4	-0.9	-4.7	0.89
		1971	20.1	21.3	1.2	6.0	0.92
		1972	24.5	23.7	-0.8	-3.3	0.79
		1973	22.1	22.4	0.3	1.4	0.91
		1974	19.4	18.1	-1.3	-6.7	1.03
		1975	23.2	22.6	-0.6	-2.5	0.80
		1976	13.5	13.5	0.0	0.0	0.89
		1977	22.9	22.1	-0.8	-3.5	0.94
		1978	26.7	25.8	-0.9	-3.4	0.75
		1979	25.5	26.2	0.7	2.7	0.69

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STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	PD	S.E. PRED.
IOWA	50	1970	24.4	22.5	-1.9	-7.5	1.43
		1971	23.2	22.4	-0.8	-3.4	1.61
		1972	25.1	25.6	0.5	2.0	1.29
		1973	24.5	25.3	0.8	3.3	1.34
		1974	19.3	23.3	4.0	20.7	1.32
		1975	23.5	24.6	1.1	4.7	1.50
		1976	21.9	22.1	0.2	0.9	1.49
		1977	21.0	19.6	-1.4	-6.7	1.93
		1978	27.0	26.5	-0.5	-1.9	1.34
		1979	26.9	26.5	-0.4	-1.5	1.28
	60	1970	24.5	24.2	-0.3	-1.2	1.55
		1971	24.3	24.1	-0.2	-0.8	1.25
		1972	24.6	26.3	1.7	6.9	1.23
		1973	23.4	25.0	1.6	6.8	1.37
		1974	19.9	25.6	5.7	28.6	2.59
		1975	24.3	26.6	2.3	9.5	1.34
		1976	22.6	25.2	2.6	11.5	1.44
		1977	26.0	26.7	0.7	2.7	1.45
		1978	25.5	26.4	0.9	3.5	1.39
		1979	28.0	27.3	-0.7	-2.5	1.38
	70	1970	21.8	23.1	1.3	6.0	1.61
		1971	21.6	21.8	0.2	0.9	1.78
		1972	23.9	23.8	-0.1	-0.4	1.50
		1973	21.6	22.7	1.1	5.1	1.91
		1974	18.9	20.0	1.1	5.8	1.55
		1975	20.9	22.6	1.7	8.1	1.44
		1976	20.6	19.7	-0.9	-4.4	1.35
		1977	23.3	21.7	-1.6	-6.9	1.60
		1978	22.8	25.7	2.9	12.7	1.51
		1979	24.7	23.7	-1.0	-4.0	1.44
	80	1970	22.1	21.5	-0.6	-2.7	2.25
		1971	21.0	20.5	-0.5	-2.4	2.43
		1972	22.4	22.9	0.5	2.2	2.02
		1973	20.0	22.2	2.2	11.0	1.97
		1974	13.6	19.2	5.6	41.2	2.45
		1975	19.4	20.6	1.2	6.2	2.07
		1976	20.2	19.4	-0.8	-4.0	1.98
		1977	20.2	21.2	1.0	5.0	2.09
		1978	20.9	23.3	2.4	11.5	2.24
		1979	22.4	20.7	-1.7	-7.5	2.00

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STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
IOWA	90	1970	23.1	21.3	-1.8	-7.8	1.30
		1971	23.7	25.2	1.5	6.3	1.51
		1972	24.3	22.4	-1.9	-7.8	1.31
		1973	21.5	21.4	-0.1	-0.5	3.23
		1974	16.8	19.6	2.8	16.7	1.60
		1975	22.6	23.3	0.7	3.1	1.46
		1976	22.6	23.4	0.8	3.5	1.42
		1977	24.8	24.8	0.0	0.0	1.28
		1978	23.4	25.5	2.1	9.0	1.27
		1979	26.4	23.3	-3.1	-11.7	1.45
STATE MODEL		1970	21.9	20.8	-1.1	-5.0	1.29
		1971	21.9	23.6	1.7	7.8	1.30
		1972	24.2	23.5	-0.7	-2.9	1.12
		1973	22.9	23.5	0.6	2.5	1.20
		1974	18.8	19.7	0.9	4.8	1.21
		1975	22.9	20.4	-2.5	-10.9	1.04
		1976	20.8	20.1	-0.7	-3.4	1.25
		1977	23.9	22.4	-1.5	-6.3	1.45
		1978	25.2	27.9	2.7	10.7	1.31
		1979	25.2	25.0	-0.2	-0.8	1.19
CRDS AGGR.		1970	21.9	21.3	-0.6	-2.7	
		1971	21.9	22.2	0.3	1.4	
		1972	24.2	23.3	-0.9	-3.7	
		1973	22.9	23.1	0.2	0.9	
		1974	18.8	21.6	2.8	14.9	
		1975	22.9	22.9	0.0	0.0	
		1976	20.8	21.1	0.3	1.4	
		1977	23.9	23.4	-0.5	-2.1	
		1978	25.2	26.1	0.9	3.5	
		1979	25.2	25.0	-0.2	-0.8	

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STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
ILLINOIS	10	1970	23.4	23.3	-0.1	-0.4	1.63
		1971	23.0	22.5	-0.5	-2.2	1.35
		1972	24.4	24.5	0.1	0.4	1.29
		1973	23.5	23.8	0.3	1.3	1.20
		1974	17.0	23.3	6.3	37.1	1.52
		1975	26.4	24.8	-1.6	-5.1	1.47
		1976	22.3	23.7	1.4	6.3	1.55
		1977	27.3	25.7	-1.6	-5.9	1.45
		1978	24.6	25.7	1.1	4.5	1.49
		1979	28.1	26.6	-1.5	-5.3	1.40
	20	1970	21.0	20.1	-0.9	-4.3	1.54
		1971	20.6	20.4	-0.2	-1.0	1.49
		1972	22.0	21.6	-0.4	-1.8	1.48
		1973	21.4	20.7	-0.7	-3.3	1.44
		1974	17.0	20.8	3.8	22.4	1.46
		1975	25.0	21.5	-3.5	-14.0	1.52
		1976	20.5	21.7	1.2	5.9	1.61
		1977	25.9	22.6	-3.3	-12.7	1.57
		1978	22.2	23.6	1.4	6.3	1.62
		1979	26.8	23.2	-3.6	-13.4	1.59
	30	1970	23.1	22.7	-0.4	-1.7	1.15
		1971	24.3	22.3	-2.0	-8.2	1.17
		1972	25.0	23.8	-1.2	-4.8	1.13
		1973	22.0	24.3	2.3	10.5	1.14
		1974	16.6	22.3	5.7	34.3	1.27
		1975	25.0	23.2	-1.8	-7.2	1.44
		1976	23.3	22.9	-0.4	-1.7	1.51
		1977	25.6	24.3	-1.3	-5.1	1.52
		1978	23.6	24.5	0.9	3.8	1.43
		1979	27.1	22.6	-4.5	-16.6	1.73
	40	1970	22.7	24.2	1.5	6.6	1.37
		1971	25.7	24.7	-1.0	-3.9	1.41
		1972	26.4	25.2	-1.2	-4.5	1.35
		1973	24.8	26.1	1.3	5.2	1.31
		1974	16.7	23.1	6.4	38.3	1.37
		1975	27.1	25.7	-1.4	-5.2	1.65
		1976	25.1	24.8	-0.3	-1.2	1.60
		1977	28.0	27.5	-0.5	-1.8	1.73
		1978	25.6	26.5	0.9	3.5	1.54
		1979	28.1	26.9	-1.2	-4.3	1.55

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STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
ILLINOIS	50	1970	23.1	23.8	0.7	3.0	1.18
		1971	25.7	24.4	-1.3	-5.1	1.32
		1972	24.4	24.9	0.5	2.0	1.22
		1973	22.7	24.9	2.2	9.7	1.13
		1974	17.6	21.7	4.1	23.3	1.25
		1975	26.4	25.0	-1.4	-5.3	1.35
		1976	23.7	23.1	-0.6	-2.5	1.32
		1977	27.3	27.9	0.5	2.2	1.55
		1978	24.9	26.0	1.1	4.4	1.25
		1979	26.8	28.1	1.3	4.9	1.30
	50	1970	21.0	22.5	1.5	7.1	1.29
		1971	23.3	24.3	1.0	4.3	1.37
		1972	24.0	22.5	-1.5	-6.3	1.23
		1973	22.0	24.2	2.2	10.0	1.25
		1974	17.8	21.9	4.1	23.0	1.40
		1975	24.3	23.1	-1.2	-4.9	1.37
		1976	23.0	21.9	-1.1	-4.[illegible]	1.48
		1977	26.6	25.1	-1.5	-5.5	1.40
		1978	22.9	24.4	1.5	5.5	1.41
		1979	27.5	24.2	-3.3	-12.0	1.54
	70	1970	18.3	18.8	0.5	2.7	1.43
		1971	19.6	21.6	2.0	10.2	1.48
		1972	21.7	20.2	-1.5	-5.9	1.45
		1973	18.6	21.0	2.4	12.9	1.45
		1974	15.2	19.6	4.4	28.9	1.59
		1975	21.6	22.0	0.4	1.9	1.52
		1976	22.3	20.5	-1.8	-8.1	1.48
		1977	24.2	21.8	-2.4	-9.9	1.53
		1978	21.9	24.1	2.2	10.0	1.51
		1979	25.1	22.9	-2.2	-8.8	1.83
	80	1970	18.0	17.1	-0.9	-5.0	1.82
		1971	17.2	19.0	1.8	10.5	1.73
		1972	20.0	19.7	-0.3	-1.5	1.71
		1973	17.2	18.5	1.3	7.5	1.67
		1974	15.4	18.6	3.2	20.8	1.75
		1975	21.6	19.5	-2.1	-9.7	1.68
		1976	17.9	19.7	1.8	10.1	1.71
		1977	23.1	19.5	-3.6	-15.6	1.69
		1978	19.2	20.6	1.4	7.3	1.73
		1979	23.3	20.9	-2.4	-10.3	1.77

APPENDIX C
BOOTSTRAP TEST RESULTS
FOR SOYBEAN YIELDS IN
IOWA, ILLINOIS, AND INDIANA
USING A CEAS MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
ILLINOIS	90	1970	15.6	15.4	-0.2	-1.3	1.40
		1971	16.2	16.7	0.5	3.1	1.35
		1972	18.7	17.3	-1.4	-7.5	1.33
		1973	15.2	16.1	0.9	5.9	1.31
		1974	13.9	16.5	2.6	18.7	1.38
		1975	19.0	17.5	-1.5	-7.9	1.33
		1976	18.1	17.7	-0.4	-2.2	1.32
		1977	20.3	17.7	-2.6	-12.8	1.30
		1978	15.1	18.0	2.9	19.2	1.34
		1979	22.0	19.6	-2.4	-10.9	1.41
STATE MODEL		1970	20.8	21.5	0.7	3.4	0.97
		1971	22.2	22.9	0.7	3.2	0.99
		1972	23.2	23.4	0.2	0.9	0.97
		1973	21.2	22.7	1.5	7.1	0.96
		1974	16.5	20.2	3.7	22.4	1.07
		1975	24.2	22.9	-1.3	-5.4	1.06
		1976	22.2	22.0	-0.2	-0.9	1.11
		1977	25.6	24.8	-0.8	-3.1	1.14
		1978	22.5	24.3	1.8	8.0	1.04
		1979	26.2	24.8	-1.4	-5.3	1.15
CRDS AGGR.		1970	20.8	21.3	0.5	2.4	
		1971	22.2	22.3	0.1	0.5	
		1972	23.2	22.4	-0.8	-3.4	
		1973	21.2	22.7	1.5	7.1	
		1974	16.5	21.0	4.5	27.3	
		1975	24.2	22.8	-1.4	-5.8	
		1976	22.2	21.9	-0.3	-1.4	
		1977	25.6	23.9	-1.7	-6.6	
		1978	22.5	24.0	1.5	6.7	
		1979	26.2	24.2	-2.0	-7.6	

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APPENDIX C
BOOTSTRAP TEST RESULTS
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USING A CEAS MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
INDIANA	10	1970	21.7	20.6	-1.1	-5.1	1.15
		1971	22.8	22.2	-0.5	-2.5	1.24
		1972	20.2	20.7	0.5	2.5	1.22
		1973	21.1	21.2	0.1	0.5	1.14
		1974	17.2	19.1	1.9	11.0	1.23
		1975	23.1	21.3	-1.8	-7.8	1.22
		1976	22.3	21.4	-0.9	-4.0	1.15
		1977	25.0	22.1	-2.9	-11.5	1.17
		1978	22.7	22.3	-0.4	-1.5	1.22
		1979	25.2	23.6	-1.6	-6.3	1.22
	20	1970	20.7	20.3	-0.4	-1.7	1.09
		1971	21.5	20.5	-1.0	-4.7	1.09
		1972	19.6	20.8	1.2	6.1	1.10
		1973	21.3	21.8	0.5	2.3	1.09
		1974	15.9	16.7	0.8	5.0	1.22
		1975	23.8	20.8	-3.0	-12.5	2.13
		1976	22.5	22.4	-0.1	-0.4	1.07
		1977	25.1	24.1	-1.0	-4.0	1.34
		1978	21.6	21.3	-0.3	-1.4	1.05
		1979	25.6	23.8	-1.8	-7.0	1.05
	30	1970	19.9	18.5	-1.4	-7.0	1.42
		1971	20.5	18.8	-1.7	-8.3	1.52
		1972	19.2	19.1	-0.1	-0.5	1.43
		1973	20.5	21.0	0.5	2.4	1.45
		1974	15.9	18.0	2.1	13.2	1.61
		1975	20.7	20.4	-0.3	-1.4	1.43
		1976	21.6	20.8	-0.8	-3.7	1.31
		1977	25.5	22.4	-3.1	-12.2	1.40
		1978	21.2	20.9	-0.3	-1.4	1.42
		1979	24.3	22.2	-2.1	-8.5	1.47
	40	1970	21.2	20.0	-1.2	-5.7	1.31
		1971	24.0	21.6	-2.4	-10.0	1.42
		1972	21.6	20.4	-1.2	-5.5	1.39
		1973	22.4	22.8	0.4	1.8	1.34
		1974	15.5	19.5	4.0	25.8	1.55
		1975	23.4	21.9	-1.5	-6.4	1.55
		1976	24.2	20.8	-3.4	-14.0	1.44
		1977	25.0	23.7	-1.3	-5.2	1.39
		1978	24.5	24.8	0.3	1.2	1.50
		1979	24.4	24.9	0.5	2.0	2.00

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APPENDIX C
BOOTSTRAP TEST RESULTS
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STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
INDIANA	50	1970	22.1	21.9	-0.2	-0.9	1.25
		1971	24.1	23.1	-1.0	-4.1	1.27
		1972	20.7	21.2	0.5	2.4	1.30
		1973	23.6	24.8	1.2	5.1	1.21
		1974	17.8	20.9	3.1	17.4	1.59
		1975	24.4	22.7	-1.7	-7.0	1.27
		1976	24.5	23.6	-0.9	-3.7	1.24
		1977	26.7	24.3	-2.4	-9.0	1.24
		1978	26.3	26.2	-0.1	-0.4	1.29
		1979	25.5	23.8	-1.7	-6.7	1.98
	60	1970	20.1	19.9	-0.2	-1.0	1.21
		1971	21.2	20.1	-1.1	-5.2	1.34
		1972	18.5	19.2	0.7	3.8	1.23
		1973	21.3	22.0	0.7	3.3	1.20
		1974	16.9	20.8	3.9	23.1	1.27
		1975	22.2	21.6	-0.6	-2.7	1.35
		1976	21.5	21.4	-0.1	-0.5	1.27
		1977	23.2	21.5	-1.7	-7.3	1.38
		1978	23.5	21.8	-1.7	-7.2	1.29
		1979	22.5	19.9	-2.6	-11.5	1.52
	70	1970	19.4	18.9	-0.5	-2.6	0.98
		1971	20.4	20.1	-0.3	-1.5	0.94
		1972	19.8	20.4	0.6	3.0	0.93
		1973	18.6	20.0	1.4	7.5	0.92
		1974	17.4	16.3	-1.1	-6.3	2.19
		1975	21.3	21.0	-0.3	-1.4	0.93
		1976	22.7	20.3	-2.4	-10.6	0.92
		1977	23.1	20.9	-2.2	-9.5	1.05
		1978	21.6	22.7	1.1	5.1	1.05
		1979	22.1	25.9	3.8	17.2	1.26
	80	1970	19.3	18.7	-0.6	-3.1	1.15
		1971	19.2	18.9	-0.3	-1.5	1.13
		1972	17.6	18.9	1.3	7.4	1.12
		1973	16.3	16.9	0.6	3.7	1.23
		1974	16.5	13.4	-3.1	-18.8	1.84
		1975	15.1	17.8	2.7	17.9	1.24
		1976	19.7	19.9	0.2	1.0	1.19
		1977	21.1	17.7	-3.4	-16.1	1.45
		1978	20.3	19.2	-1.1	-5.4	1.24
		1979	19.8	19.2	-0.6	-3.0	1.21

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APPENDIX C
BOOTSTRAP TEST RESULTS
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IOWA, ILLINOIS, AND INDIANA
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STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
INDIANA	90	1970	18.9	18.8	-0.1	-0.5	1.52
		1971	19.7	18.3	-1.4	-7.1	1.54
		1972	16.1	18.3	2.2	13.7	1.52
		1973	15.7	17.7	2.0	12.7	1.62
		1974	17.3	16.0	-1.3	-7.5	2.04
		1975	17.6	18.7	1.1	6.3	1.54
		1976	21.8	18.9	-2.9	-13.3	1.51
		1977	22.0	20.1	-1.9	-8.5	1.77
		1978	19.7	20.2	0.5	2.5	1.73
		1979	19.9	17.4	-2.5	-12.5	1.71
STATE MODEL		1970	20.8	20.2	-0.6	-2.9	0.84
		1971	22.2	21.3	-0.9	-4.1	0.90
		1972	19.8	20.1	0.3	1.5	0.90
		1973	21.2	22.6	1.4	6.5	0.84
		1974	16.8	19.5	2.7	16.1	1.07
		1975	22.5	21.3	-1.2	-5.3	1.08
		1976	22.9	21.3	-1.5	-7.0	0.91
		1977	24.9	23.1	-1.8	-7.2	1.05
		1978	23.2	23.6	0.4	1.7	0.95
		1979	24.2	23.3	-0.9	-3.7	1.34
CRDS AGGR.		1970	20.8	20.2	-0.6	-2.9	
		1971	22.2	21.1	-1.1	-5.0	
		1972	19.8	20.3	0.5	2.5	
		1973	21.2	21.9	0.7	3.3	
		1974	16.8	18.8	2.0	11.9	
		1975	22.5	21.3	-1.2	-5.3	
		1976	22.9	21.6	-1.3	-5.7	
		1977	24.9	22.7	-2.2	-8.9	
		1978	23.2	23.0	-0.2	-0.9	
		1979	24.2	23.2	-1.0	-4.1	

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APPENDIX C
BOOTSTRAP TEST RESULTS
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USING A CEAS MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
REGION	CRDS AGGR.	1970	21.2	21.1	-0.1	-0.5	
		1971	22.1	22.0	-0.1	-0.5	
		1972	22.8	22.2	-0.6	-2.5	
		1973	21.8	22.7	0.9	4.1	
		1974	17.4	20.8	3.4	19.5	
		1975	23.4	22.6	-0.8	-3.4	
		1976	21.8	21.5	-0.3	-1.4	
		1977	24.8	23.5	-1.3	-5.2	
		1978	23.6	24.6	1.0	4.2	
		1979	25.5	24.3	-1.2	-4.7	
STATES	AGGR.	1970	21.2	21.0	-0.2	-0.9	
		1971	22.1	22.8	0.7	3.2	
		1972	22.8	22.7	-0.1	-0.4	
		1973	21.8	23.0	1.2	5.5	
		1974	17.4	19.9	2.5	14.4	
		1975	23.4	21.7	-1.7	-7.3	
		1976	21.8	21.2	-0.6	-2.8	
		1977	24.8	23.6	-1.2	-4.8	
		1978	23.6	25.5	1.9	8.1	
		1979	25.5	24.6	-0.9	-3.5	

APPENDIX D

Significance of Variables Included in CRD and State Models for Soybean Yields in Iowa

ns = not significant   * = significant at .10 level

** = significant at .05 level   ** = significant at .01 level

Variable/Model	10	20	30	40	50	60	70	80	90	ST
Trend 1	***	***	***	***	***	***	***	***	ns	***
Trend 2	***	***	***	***	***	***	***	***	***	***
June Temp			***							
CPREC Apr			***	***	***					
May							**			*
DFNT Apr							***	***		
May				***						
Jun		**			***					
Jul										
Aug					***					
Sep	***			***			***	ns		**
DFNP Jun										
Jul									***	
Aug										
Sep										
SDFNP May										
Jun										
Jul										
Aug										

APPENDIX D

(Iowa cont.)

Variable/Model		10	20	30	40	50	60	70	80	90	ST
DEF	May										
	Jun								***		
	Jul										
	Aug										
RATIO	May							***			
	Jun							**			
	Jul			***	***	***					***
	Aug	***				***	***	***	ns		
	Sep	***	**							*	***
Intercept		***	***	***	***	***	***	***	ns	ns	***

APPENDIX D

Significance of Variables Included in CRD and State Models for Soybean Yields in Illinois

ns = not significant   * = significant at .10 level

** = significant at .05 level   *** = significant at .01 level

Variable/Model		10	20	30	40	50	60	70	80	90	ST
Trend 1		***	***	***	***	***	***	***	***	***	***
Trend 2		***	***	***	***	***	***	***	***	***	***
CPREC	Apr										
	May						***				**
DFNT	Apr										
	May										
	Jun	**				**					
	Jul										
	Aug										
	Sep										
DFNP	Jun										
	Jul				***						
	Aug				**						***
	Sep										
SDFNP	May	***	**								
	Jun			ns				*			
	Jul				***	***	***	***			
	Aug										

APPENDIX D

(Illinois cont.)

Variable/Model		10	20	30	40	50	60	70	80	90	ST
DEF	May			***							
	Jun			**							
	Jul					***	***	***	***	***	***
	Aug					***	•	***			
RATIO	May										
	Jun										
	Jul			***			*				
	Aug	***	**	ns					***	***	
	Sep			ns			ns				ns
Intercept		***	ns	***	***	***	ns	***	***	ns	***

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APPENDIX D

Significance of Variables Included in CRD and State Models for Soybean Yields in Indiana

ns = not significant * = significant at .10 level

** = significant at .05 level ** = significant at .01 level

Variable/Model		10	20	30	40	50	60	70	80	90	ST
Trend		***	***	***	***	***	***	***	***	***	***
CPREC	Apr								***		
	May										
DFNT	Apr										
	May						*		**	*	*
	Jun	**		*	*	***	**				***
	Jul			*							
	Aug								**		
	Sep										
DFNP	Jun		**							ns	
	Jul	***	***			***					***
	Aug				**		***				
	Sep									**	
SDFNP	May					**				*	
	Jun							**			
	Jul		***	***	***	***					**
	Aug		***					***	***	**	

APPENDIX D

(Indiana cont.)

Variable/Model		10	20	30	40	50	60	70	80	90	ST
DEF	May										
	Jun										
	Jul				***			***			
	Aug							***			
RATIO	May										
	Jun										
	Jul								**		
	Aug	***	***	***		***	***		***	***	***
	Sep			ns					**		
Intercept		ns	ns	ns	***	*	***	***	ns	ns	ns